JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXI. MARCH, 1881. No. 3.

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

ON THE EXPERIMENTS WITH THE PERKINS MACHINERY OF THE STEAM YACHT "ANTHRACITE."

By Chief-Engineer ISHERWOOD, United States Navy.

(Continued from page 99.)

THE ENGLISH EXPERIMENT WITH THE "ANTHRACITE."

The experiment made in England with the *Anthracite* in free route, was conducted by Mr. Bramwell, whose report is before me together with *fac similes* of all the indicator diagrams taken on that occasion, and the working drawings of the cylinders, valve chest, etc. The text of the report is exceedingly meagre, giving but little information beyond the fact of the number of pounds of coal per hour for which the indicated horse-power was obtained. Neither the manner of conducting the experiment, nor of reporting it, is comparable, in sagacity of method and completeness of data and results, with the New York Navy Yard experiment and report made by Chief Engineer Loring, U. S. N., and were it not for the possession of the indicator diagrams and of the working drawings of the cylinders above referred to, but little could be elicited from Mr. Bramwell's report of value to the engineer.

Mr. Bramwell's method was to commence with the boiler and its water cold, weigh all the coal, including the coal equivalent of the

kindling wood, consumed from the starting of the fire, and, at the close of the experiment, burn the fire entirely out, working the machinery and taking the diagrams until the engine stopped for want of steam. The work done during this time was computed in foot-pounds from the diagrams, which work could be easily turned into indicated horses-power. This method was unfair to the machinery. The heating of the boiler and its contained water to the working temperature is not properly chargeable to the performance of the engine, nor is it exact to average the declining power of the engine during the burning out of the fire with its proper performance at normal pressure. As the steam pressure sunk with the sinking fire during the latter part of the experiment, the back pressure against the piston remaining constant, the indicated pressure became continuously a less and less proportion of the total pressure on the pistons with a corresponding falling off in the economic result.

The proper manner was to commence the experiment with the fire in normal condition for steady action, and to end with it in the same state, maintaining the steam pressure and rate of combustion as uniform as possible throughout, and continuing the experiment sufficiently long to render any error in the valuation of the condition of the fire at the beginning and end practically insensible when spread over such an extent of time.

Among the omissions in the report is the height of the barometer, which has been supplied by assuming it at the standard of 29·92 inches of mercury. The height of the barometer is indispensable for obtaining the pressures above zero from the indicator diagrams, and without these pressures the distribution of the steam in the cylinders cannot be known. The information to be thus obtained from these diagrams is very important, and is much in addition to merely the indicated pressure which is usually, as in Mr. Bramwell's report, all that is derived from them. The pressure above zero at the commencement of the stroke of the piston, at the point of cutting off the steam, and at the end of the stroke of the piston; the mean back pressure against the piston during its stroke, and the back pressure at the commencement of its stroke, should always be given as well as the indicated pressure.

The refuse from the coal is not stated, but as the fuel used was Nixon's navigation coal, the refuse from which is known by other experiments to be about 5 per centum, that proportion has been

assumed. This coal is the finest steam coal in the world, and is used exclusively in experiments made for the British Admiralty. As it comes from the mine it has but little refuse, and that little is afterwards lessened by careful hand picking. It produces neither smoke nor clinker, the refuse being a small quantity of light white ash. It is free burning to a remarkable degree, does not cake, intumesce or cohere, and requires but little cleaning of the fire. The pound of its combustible matter, that is, a pound of what remains after deduction of the refuse, has, undoubtedly, a higher water vaporizing value in a boiler than the pound of combustible matter from any other coal known.

No temperatures are given in the report, not even the temperature of the feed water, which has been assumed the same as during the Navy Yard experiment, the vacuum in the condenser being very nearly alike in both cases.

The waste spaces in the steam passages and clearances at the ends of the cylinders are not given in the report, although their disproportionately great extent materially affects opinion on the performance. No statement is made of where the water level was carried, nor is there given the proportion of the boiler surface in water and in steam. The text of the report, indeed, furnishes no means of intelligently understanding the performance, or of analyzing it; but its omissions have been supplied from the other sources, so that the complete data and results are presented in the following table with probably sufficient accuracy for practical purposes.

The weight of water pumped into the boiler during the English experiment was not ascertained; it is a very important quantity and might easily have been measured in the same manner as during the Navy Yard experiment, the quantity per hour being so small as to be quite manageable. In the following table, however, this quantity is given, and it was thus deduced. From the Navy Yard experiment the number of pounds of steam condensed per hour in the third cylinder at the end of the stroke of its piston by causes other than the production of the power, was experimentally ascertained, but as the extreme temperatures in this cylinder during the two experiments were different, the difference being less in the English trial, the Navy Yard condensation had to be diminished in the ratio of the two differences. To the quantity so obtained were added the number of pounds of steam accounted for per hour by the indicator at the end of the stroke

of the piston of the third cylinder, and the sum is the number of pounds of feed water pumped into the boiler per hour. This quantity is indispensable for understanding and reconciling the differences in the economic results obtained during the two experiments; the error in it, if there be any, cannot exceed one or two per centum.

The length of the trial has been taken at 11 hours and 10 minutes, as for that time only can the coal consumption be recovered for the proper conditions of the trial. The indicator diagrams taken half-hourly during this time have all been calculated, and the mean number of double strokes made by the pistons of the engine for the same time has also been found. The mean steam pressure in the boiler and in the receiver during this time is also ascertained, as well as the mean vacuum in the condenser. The consumption of coal was obtained as follows:

From 7.22 A. M. until 6.30 P. M., a period of 11 hours and 10 minutes consecutively, the engine operated with great uniformity of conditions, the steam pressure in the boiler varying from 340 pounds per square inch above the atmosphere as the minimum to 370 pounds as the maximum, the mean being 357 pounds per square inch above the atmosphere. The quantity of coal consumed during this period is not stated in the report, but the statement is made therein that from 7.50 A. M. until 4.45 P. M., a period of 8 hours and 55 minutes comprised within the above, 1232 pounds of coal were thrown into the furnace. If the assumption be now made that the condition of the fire was the same when the last of this coal was thrown in as it was when the first was thrown in, which was undoubtedly the case judging from the uniformity of the steam pressure and number of double strokes made by the pistons before and after as well as during the period of 8 hours and 55 minutes, then the 1232 pounds of coal were consumed in the 8 hours and 55 minutes, or at the rate of 138·168224 pounds per hour, or 9·0213 pounds per hour per square foot of grate surface, which, for the kind of coal used, was an extremely slow combustion. The mean number of double strokes made per minute by the pistons of the engine during the above 11 hours and 10 minutes, was 130·3881, and is exactly the same as during the 8 hours and 55 minutes, the mean steam pressure in the boiler being also almost exactly the same during the two periods. The above rate of combustion of 138·16824 pounds of coal per hour, according to the report, during

the 8 hours and 55 minutes, may therefore be considered the mean rate of combustion for the entire period of 11 hours and 10 minutes.

Table containing the Data and Results of the Experiment made in England by Mr. Bramwell on the Machinery of the Steam Yacht ANTHRACITE *to determine its Economic Performance:*

	Date of the experiment (vessel in free route),	May 22, 1880.
	Number of sets of indicator diagrams, taken half-hourly,	22
Total Quantities.	Duration of the experiment in hours and minutes, consecutively,	11·10
	Total number of pounds consumed of Nixon's navigation steam coal,	1542·8785
	Total number of pounds of refuse in ash, etc., from the coal,	77·1439
	Total number of pounds of combustible (gasifiable portion of the coal) consumed,	1465·7346
	Per centum of the coal in refuse of ash, etc.,	5·
	Total number of double strokes made by the pistons of the engine,	87360·
Engine.	Steam pressure in the boiler, in pounds per square inch above the atmosphere,	357·0
	Steam pressure in the receiver, in pounds per square inch above the atmosphere,	9·4
	Position of the throttle valve,	Partly closed.
	Fraction completed of the stroke of the piston of the 1st cylinder when the steam was cut off,	0·4887
	Fraction completed of the down stroke of the piston of the 3d cylinder when the steam was cut off,	0·2937
	Fraction completed of the up stroke of the piston of the 3d cylinder when the steam was cut off,	0·3222
	Number of times the steam was expanded,	26·8851
	In none of the cylinders was the steam cushioned, nor was there either steam or exhaust lead.	
	Vacuum in the condenser, in inches of mercury,	26·864
	Back pressure in the condenser in pounds per square inch above zero,	1·501
	Probable temperature in degrees Fahrenheit, of the feed water,	122·
	Number of double strokes made per minute by the steam pistons,	130·3881
	Temperature, in degrees Fahrenheit, of the boiler steam, considered as saturated,	430·48
	Temperature, in degrees Fahrenheit, of the steam in the 1st cylinder at the commencement of the stroke of the piston, considered as saturated,	385·28

Rate of Combustion.	Pounds of coal consumed per hour,	138·1682
	Pounds of combustible consumed per hour,	131·2598
	Pounds of coal consumed per hour per square foot of grate,	9·0213
	Pounds of combustible consumed per hour per square foot of grate,	8·5702
	Pounds of coal consumed per hour per square foot of outer heating surface,	0·4602
	Pounds of coal consumed per hour per square foot of inner heating surface,	0·6127
	Pounds of combustible consumed per hour per square foot of outer heating surface,	0·4372
	Pounds of combustible consumed per hour per square inner heating surface,	0·5821
Steam Pressure in 1st Cylinder Per Indicator.	Pressure on piston of 1st cylinder at commencement of its stroke, in pounds per square inch above zero,	205·03
	Pressure on piston of 1st cylinder at the point of cutting off the steam, in pounds per square inch above zero,	181·51
	Pressure on piston of 1st cylinder at the end of its stroke, in pounds per square inch above zero,	105·26
	Mean back pressure against piston of 1st cylinder during its stroke, in pounds per square inch above zero,	41·23
	Back pressure against piston of 1st cylinder at commencement of its stroke, in pounds per square inch above zero,	32·30
	Indicated pressure on piston of 1st cylinder, in pounds per square inch,	124·546
	Net pressure on piston of 1st cylinder, in pounds per square inch,	122·546
	Total pressure on piston of 1st cylinder, in pounds per square inch,	165·776
Steam Pressures in 2d Cylinder Per Indicator.	Pressure on piston of 2d cylinder at commencement of its stroke, in pounds per square inch above zero,	62·33
	Pressure on piston of 2d cylinder at the end of its stroke, in pounds per square inch above zero,	29·83
	Mean back pressure against piston of 2d cylinder during its stroke, in pounds per square inch above zero,	25·94
	Back pressure against piston of 2d cylinder at commencement of its stroke, in pounds per square inch above zero,	24·10
	Indicated pressure on piston of 2d cylinder, in pounds per square inch,	15·606
	Net pressure on piston of 2d cylinder, in pounds per square inch,	13·606
	Total pressure on piston of 2d cylinder, in pounds per square inch,	41·456

Steam Pressures in 3d Cylinder Per Indicator, Down Stroke.	
Pressure on top of piston of 3d cylinder at commencement of its stroke, in pounds per square inch above zero,	20·06
Pressure on top of piston of 3d cylinder at the point of cutting off the steam, in pounds per square inch above zero,	16·77
Pressure on top of piston of 3d cylinder at the end of its stroke, in pounds per square inch above zero,	7·02
Mean back pressure against top of piston of 3d cylinder during its stroke, in pounds per square inch above zero,	4·05
Back pressure against top of piston of 3d cylinder at commencement of its stroke, in pounds per square inch above zero,	3·64
Indicated pressure on top of piston of 3d cylinder, in pounds per square inch,	8·252
Net pressure on top of piston of 3d cylinder, in pounds per square inch,	6·252
Total pressure on top of piston of 3d cylinder, in pounds per square inch,	12·302
Weight of Steam Accounted for by the Indicator.	
Pounds of steam present per hour in the 1st cylinder at the point of cutting off the steam, calculated from the pressure there,	989·3756
Pounds of steam present per hour in the 1st cylinder at the end of the stroke of its piston, calculated from the pressure there,	890·6505
Pounds of steam condensed per hour in the 1st cylinder to furnish the heat transmitted into the total horses-power developed in that cylinder by the expanded steam alone,	45·1639
Sum of the two immediately preceding quantities,	935·8144
Pounds of steam present per hour in the 2d cylinder at the end of the stroke of its piston, calculated from the pressure there,	1004·7334
Pounds of steam condensed per hour in the 1st and 2d cylinders to furnish the heat transmitted into the total horses-powers developed in those cylinders by the expanded steam alone,	124·8752
Sum of the two immediately preceding quantities,	1129·6086
Pounds of steam present per hour in the 3d cylinder at the end of the stroke of its piston, calculated from the mean of the pressures there for the down stroke and the up stroke of the piston,	1118·3780
Pounds of steam condensed per hour in the 1st, 2d and 3d cylinders to furnish the heat transmitted into the total horses-power developed in those cylinders, by the expanded steam alone,	199·1154
Sum of the two immediately preceding quantities,	1317·4934

Steam Pressures in 3d Cylinder Per Indicator, Up stroke.	
Pressure on bottom of piston of 3d cylinder at commencement of its stroke, in pounds per square inch above zero,	21·94
Pressure on bottom of piston of 3d cylinder at the point of cutting off the steam, in pounds per square inch above zero,	17·55
Pressure on bottom of piston of 3d cylinder at the end of its stroke, in pounds per square inch above zero,	7·66
Mean back pressure against bottom of piston of 3d cylinder during its stroke, in pounds per square inch above zero,	4·44
Back pressure against bottom of piston of 3d cylinder at commencement of its stroke, in pounds per square inch above zero,	4·05
Indicated pressure on bottom of piston of 3d cylinder, in pounds per square inch,	10·247
Net pressure on bottom of piston of 3d cylinder, in pounds per square inch,	8·247
Total pressure on bottom of piston of 3d cylinder, in pounds per square inch,	14·687
Horses-Power.	
Indicated horses-power developed in the 1st cylinder,	29·0173
Indicated horses-power developed in the 2d cylinder,	14·6746
Indicated horses-power developed in the 3d cylinder (down stroke of piston),	16·6570
Indicated horses-power developed in the 3d cylinder (up stroke of piston),	20·3834
Aggregate indicated horses-power developed in all the three cylinders,	80·7323
Net horses-power developed in the 1st cylinder,	28·5514
Net horses-power developed in the 2d cylinder,	12·7940
Net horses-power developed in the 3d cylinder (down stroke of piston),	12·6199
Net horses-power developed in the 3d cylinder (up stroke of piston),	16·4050
Aggregate net horses-power developed in all the three cylinders,	70·3703
Total horses-power developed in the 1st cylinder,	38·6233
Total horses-power developed in the 2d cylinder,	29·3869
Total horses-power developed in the 3d cylinder (down stroke of piston),	13·2643
Total horses-power developed in the 3d cylinder (up stroke of piston),	15·4050
Aggregate total horse-power developed in all the three cylinders,	96·6795
Total horses-power developed by the expanded steam alone in the 1st cylinder,	15·6233
Total horses-power developed by the expanded steam alone in the 2d cylinder,	29·3869
Total horses-power developed by the expanded steam alone in the 3d cylinder,	28·6693

Weight of Water Vaporized in the Boiler from the Feed Temperature.	
Pounds of steam evaporated per hour in the boiler on the supposition that this weight was equal to the weight of steam accounted for by the indicator at the end of the stroke of the piston of the 3d cylinder plus 121·9992 pounds condensed in that cylinder by other causes than the development of the power; this 121·9992 pounds is calculated from the weight of 147·2538 pounds condensed per hour in the 3d cylinder during the experiment made at the New York Navy Yard on the machinery of the *Anthracite*, divided by the ratio 1·207 of the difference between the temperatures of the initial steam in that cylinder on its piston and of the back pressure steam against it at the commencement of the stroke in that experiment and in the present one. In the Navy Yard experiment the temperature of the initial steam on the piston of the 3d cylinder was 245·76 degrees Fahrenheit, and the temperature of the minimum back pressure against that piston was 150·25 degrees Fahrenheit; difference 95·51 degrees Fahrenheit. In Mr. Bramwell's experiment the temperature of steam of the initial pressure on the piston of the 3d cylinder was 230·60 degrees Fahrenheit, and the temperature of the minimum back pressure against it was 151·47 degrees Fahrenheit; difference 79·13 Fahrenheit. And $\frac{95 \cdot 51}{79 \cdot 13} = 1 \cdot 207$, the ratio used above, ...	1439·4926
Economic Results.	
Pounds of coal consumed per hour per indicated horse-power, ...	1·7114
Pounds of coal consumed per hour per net horse-power,	1·9634
Pounds of coal consumed per hour per total horse-power,	1·4291
Pounds of combustible consumed per hour per indicated horse-power, ...	1·6259
Pounds of combustible consumed per hour per net horse-power, ...	1·8653
Pounds of combustible consumed per hour per total horse-power, ...	1·3577
Pounds of feed water consumed per hour per indicated horse-powef, ...	17·8304
Pounds of feed water consumed per hour per net horse-power, ...	20·4560
Pounds of feed water consumed per hour per total horse-power, ...	14·8893
Fahrenheit units of heat consumed per hour per indicated horse-power, ...	20021·7027
Fahrenheit units of heat consumed per hour per net horse-power, ...	22969·9810
Fahrenheit units of heat consumed per hour per total horse-power, ...	16719·1503

Difference Between the Weight of Water Vaporized in the Boiler and the Weight of Steam Accounted for by the Indicator.	
Difference in pounds per hour, between the weight of water vaporized (1439·4926 pounds) in the boiler and the weight of steam accounted for by the indicator in the 1st cylinder at the point of cutting off the steam,	450·1170
Difference in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the 1st cylinder at the point of cutting off the steam, . .	31·27
Difference in pounds per hour, between the weight of water vaporized in the boiler and the weight of steam accounted for by the indicator in the 1st cylinder at the end of the stroke of its piston, . . .	503·6782
Difference in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the 1st cylinder at the end of the stroke of its piston, . .	34·99
Difference in pounds per hour, between the weight of water vaporized in the boiler and the weight of steam accounted for by the indicator in the 2d cylinder at the end of the stroke of its piston, . . .	309·8840
Difference in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the 2d cylinder at the end of the stroke of its piston, . .	21·53
Difference in pounds per hour, between the weight of water vaporized in the boiler and the weight of steam accounted for by the indicator in the 3d cylinder at the end of the stroke of its piston, . . .	121·9992
Difference in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the 3d cylinder at the end of the stroke of its piston, . .	8·47
Boiler Vaporization.	
Number of pounds of water that would have been vaporized in the boiler per hour had the feed water been supplied at the temperature of 100 degrees Fahrenheit and vaporized under the atmospheric pressure of 29·92 inches of mercury, ...	1498·7042
Number of pounds of water that would have been vaporized in the boiler per hour had the feed water been supplied at the temperature of 212 degrees Fahrenheit and vaporized under the atmospheric pressure of 29·92 inches of mercury, ...	1673·8137
Pounds of water vaporized from 100 degrees Fahrenheit by one pound of coal, ...	10·8469
Pounds of water vaporized from 100 degrees Fahrenheit by one pound of combustible, . . .	11·4179
Pounds of water vaporized from 212 degrees Fahrenheit by one pound of coal, ...	12·1143
Pounds of water vaporized from 212 degrees Fahrenheit by one pound of combustible, . . .	12·7519

PER CENTUM OF TOTAL PRESSURE ON PISTONS UTILIZED AS INDICATED AND AS NET PRESSURES.

Mean indicated pressure on the piston of the 3d cylinder, equivalent to the sum of the indicated pressure on that piston and of the indicated pressures on the pistons of the 2d and 1st cylinders reduced respectively in the ratio of the areas of the pistons of the 2d and 1st cylinders to that of the 3d cylinder, and for the fact of the 2d and 1st cylinders being single acting, while the 3d cylinder is double acting, in pounds per square inch, ...	20·1464
Mean total pressure which applied to the piston of the 3d cylinder would produce the total horses-power developed by the engine, provided the indicated pressure on that piston was the above 20·1464 pounds per square inch, ...	24·1231
Per centum of the mean total pressure on the pistons of the three cylinders utilized as indicated pressure, .	83·50
Mean net pressure on the piston of the 3d cylinder, equivalent to the sum of the net pressure on that piston and of the net pressures on the pistons of the 2d and 1st cylinders reduced respectively in the ratio of the areas of the pistons of the 2d and 1st cylinders to that of the 3d cylinder, and for the fact of the 2d and 1st cylinders being single acting, while the 3d cylinder is double acting, in pounds per square inch, . .	17·5608
Per centum of the mean total pressure on the pistons of the three cylinders utilized as net pressure, . .	72·80

COMPARISON OF THE TWO EXPERIMENTS.

The most cursory glance at the results of the experiment made on the machinery of the *Anthracite* by the Board of Naval Engineers at New York, and by Mr. Bramwell in England, shows a wide difference, and it will be interesting and instructive to trace the cause and to reconcile the discrepancy. This seems a difficult task when the indicated horse-power cost in the former experiment 2·7115 pounds of coal per hour, and in the latter experiment 1·7114 pounds, yet this chasm can be bridged.

Referring, now, to the tables containing the data and results of the experiments, it will be seen from the quantities grouped under the head of "difference between the weight of water vaporized in the boiler and the weight of steam accounted for by the indicator" that the proportion which the latter is of the former is greatly less in the experiment made by the Naval Engineers than in Mr. Bramwell's experiment; in other words, the cylinder condensation was much

greater in the Engineers' experiment than it was in Mr. Bramwell's. The following are the exact figures for the periods stated.

	Experiment by Board of Naval Engineers.	Experiment by Mr. Bramwell.
Difference in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the first cylinder at the point of cutting off the steam,	56·76	31·27
Difference in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the first cylinder at the end of the stroke of its piston,	56·22	34·99
Difference in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the second cylinder at the end of the stroke of its piston,	38·41	21·53
Difference in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator in the third cylinder at the end of the stroke of its piston,	10·05	8·47

In the Engineers' experiment the pressure of the steam at the commencement of the stroke of the piston of the first cylinder was 201·64 pounds per square inch above zero, and in Mr. Bramwell's experiment it was 205·03 pounds. The back-pressure against the piston of the third cylinder was very nearly the same in both experiments, so if the steam was in the same condition as regards superheating in both experiments, the difference between the extreme temperatures in the cylinders in both cases was insignificant, and this difference is a measure—other things equal—of the cylinder condensation. But so far from other things being equal, there were great inequalities during the two experiments in two important particulars. 1st. The steam, though greatly throttled in the Engineers' experiment by the small cross area of the steam pipe, notwithstanding the throttle valve was kept wide open, was much more throttled in Mr. Bramwell's experiment by the combined small area of the steam pipe and the partial closing of the throttle valve. The throttling in the first case caused a reduction of the boiler pressure of 129·59 pounds per square inch when the steam entered the first cylinder, and in the second case caused

a similar reduction of 166·66 pounds per square inch. The superheating in the first case, due to the difference between the temperature of the steam in the boiler and its temperature in the first cylinder at the beginning of the stroke of its piston, was 35 degrees Fahrenheit, and in the second case the similar superheating was 45 degrees Fahrenheit. In the second case, also, the engine was supplied, owing to the greater throttling, with drier steam, independently of the superheating. Both the causes just stated operate to lessen the cylinder condensation more in Mr. Bramwell's than in the Engineers' experiment.

2d. In Mr. Bramwell's experiment the pistons of the engine made 130·3881 double strokes per minute, while, in the Engineers' experiment, they made only 103·02782 double strokes. The initial, final and mean pressures on the pistons were nearly the same in both experiments, the greater number of double strokes of pistons in equal time made during Mr. Bramwell's experiment being due to the fact that the vessel was then in free route, while during the Engineers' experiment she was held stationary to the dock. Now, with *the just mentioned pressures on the pistons maintained constant*, the weight of steam consumed per hour by the engine would be in the ratio of the number of double strokes made by the pistons, while the weight of steam condensed per hour in the cylinder would remain sensibly constant, the interior surfaces of the cylinder being in both cases half the time exposed to the steam temperature and half the time to the exhaust temperature, so that although the cylinder condensation remained constant in weight of steam condensed per hour, yet this weight becomes a less and less proportion of the weight of steam evaporated per hour in the boiler as the speed of the piston becomes greater and greater; hence, there is an economic gain with increased speed of piston, *the piston pressure remaining constant.* These remarks, however, apply only when cylinder condensation exists, and in proportion to its extent, the gain being due wholly to the lessening of the per centum of that condensation. When no such condensation exists the cost of the power in heat is unaffected by the speed of the piston.

The per centum of cylinder condensation should, owing to the above causes, be certainly less in Mr. Bramwell's than in the Engineers' experiment, and the determinations show the difference to be very considerable, as might be expected from the great percentage of this condensation in the Engineers' experiment. For example, the difference

between the weight of steam condensed at the point of cutting off in the first cylinder is, in the two experiments, (56·76 — 31·27 =) 25·49 per centum of the weight evaporated in the boiler. At the end of the stroke of the piston of the first cylinder it is (56·22 — 34·99 =) 21·23 per centum. At the end of the stroke of the piston of the second cylinder it is (38·41 — 21·53 =) 16·88 per centum. And at the end of the stroke of the piston of the third cylinder it is (10·05 — 8·47 =) 1·58 per centum.

There must now be examined whether the difference in the per centum of the cylinder condensations in the two experiments will account for the difference in the heat cost of the powers developed respectively.

In the first cylinder, during the Engineers' experiment, there were utilized of the total weight of steam evaporated in the boiler (100·00 — 56·22 =) 43·78 per centum; but if the cylinder condensation had been the same per centum as during Mr. Bramwell's experiment the percentage utilized would have been (100·00—34·99=) 65·01, so that the total horses-power developed in that cylinder during the Engineers' experiment, instead of being 28·8902, would have been $\left(\frac{28{\cdot}8902 \times 65{\cdot}01}{43{\cdot}78} = \right) 42{\cdot}9000.$

In the second cylinder, during the Engineers' experiment, there were utilized of the total weight of steam evaporated in the boiler (100·00 — 38·41 =) 61·59 per centum; but if the cylinder condensation had been the same per centum as during Mr. Bramwell's experiment the percentage utilized would have been (100·00—21·53=) 78·47, so that the total horses-power developed in that cylinder during the Engineers' experiment, instead of being 23·2490, would have been $\left(\frac{23{\cdot}2490 \times 78{\cdot}47}{61{\cdot}59} = \right) 30{\cdot}8949.$

In the third cylinder, during the Engineers' experiment, there were utilized of the total weight of steam evaporated in the boiler (100·00 — 10·05 =) 89·95 per centum; but if the cylinder condensation had been the same per centum as during Mr. Bramwell's experiment the percentage utilized would have been (100·00—8·47=) 91·53, so that the total horses-power developed in that cylinder during the Engineers' experiment, instead of being 28·0135, would have been $\left(\frac{28{\cdot}0133 \times 91{\cdot}53}{89{\cdot}95} = \right) 28{\cdot}5054.$

The sum of the above new total horses-power is (42·9000+30·8949 +28·5054=) 102·3003, which is what the engine would have developed during the Engineers' experiment with the weight of steam then evaporated in the boiler, had the cylinder condensation been the same per centum as in Mr. Bramwell's experiment. Dividing the weight of steam evaporated in the boiler during the engineers' experiment by the new total horses-power, there results for the cost of the total horse-power $\left(\frac{1465{\cdot}11822}{102{\cdot}3003}=\right)$14·3217 pounds of feed-water per hour, equivalent to (14·3217 × 1121·4 =) 16060·3992 Fahrenheit units of heat. In Mr. Bramwell's experiment the total horse-power cost 14·8893 pounds of feed water per hour, equivalent to 16719·1503 Fahrenheit units of heat, the discrepancy being about 4 per centum of the greater quantity, a very close approximation, which includes all errors of observation, calculation and assumption. It is therefore clear that the difference in the cost of the power during the two experiments was wholly due to and measured by the difference of the cylinder condensations, and no other reason can be given why the condensations should have differed so widely than the less amount of superheating possessed by the boiler steam in one experiment than in the other, and the greatly less speed of piston with equal piston pressures.

Taking, in the case of the two experiments, the number of Fahrenheit units of heat consumed per hour per total horse-power for the measure of the economic results, and assuming that cost in the engineers' experiment as unity, the performance of the machinery in Mr. Bramwell's experiment was $\left(\frac{20498{\cdot}22 - 16719{\cdot}15 \times 100}{20498{\cdot}22}=\right)$ 18·346 per centum superior. This 18·346 per centum was the measure of the gain obtainable from the greater degree of superheating possessed by the boiler steam in the latter experiment, and the greater speed of piston with equal piston pressures, a gain not difficult to realize by these means in an engine having the excessive cylinder condensations of that of the *Anthracite*.

The gain due to superheating, *per se*, which is as obtainable from one kind of machinery as another, must be kept separate. It is one thing, and any gain due to high boiler pressures and large measures of expansion is another thing of a totally different kind. The two should not be mingled and confused in comparing the performances of different methods of using steam.

When experiments are made on machinery employing superheated steam the temperature of the steam must be accurately given, otherwise the results are misleading, unintelligible and incapable of correct comparison with those of experiments in which saturated steam, or steam of a lower or higher or lower degree of superheating is employed.

The relative water vaporizing powers of the different coal used in the two experiments may be ascertained from the data corrected for the difference in the conditions. Mr. Bramwell's experiment lasted 11 hours and 10 minutes consecutively; "Nixon's Navigation Coal" was burned with slow combustion, giving only 5 per centum refuse in the form of a loose white ash without clinker, consequently there was no cleaning of the fire requiring the furnace door to be kept open long enough for breaking up and removing clinker; the fire only needed pricking from below the grate. The Engineers' experiment lasted 23 hours and 58 minutes consecutively; semi-bituminous coal of a quality below the average was burned at a higher rate of combustion, giving 17·6363 per centum refuse, one-half of which was clinker in large masses requiring the furnace door to be kept open long enough to break it from the grate and remove it through the door. The results of several very complete experiments on the "Murphy shaking grate, etc.," made in 1878 by a Board of Chief Engineers of the Navy, of which the writer was the presiding officer, showed that the combustible portion of coal underwent an economic loss of 0·3935 per centum for every one per centum the crude coal contained in refuse removed through the furnace door. Accepting this determination, the combustible portion of the coal consumed during the engineers' experiment was reduced in vaporizative power ($17{\cdot}6363 \times 0{\cdot}3935 =$) 6·9399 per centum relatively to the coal consumed in Mr. Bramwell's experiment, on which no such reduction is to be made.

The pound of the combustible portion of the coal vaporized, in Mr. Bramwell's experiment, from the temperature of 212 degrees Fahrenheit and under the standard atmospheric pressure, 12·7519 pounds of water.

The pound of the combustible portion of the coal vaporized, in the Engineers' experiment, from the same temperature and under the same pressure, 11·2515 pounds of water, which, corrected for the above 6·9399 per centum due to the refuse, becomes ($100{\cdot}0000 - 6{\cdot}8399 : 11{\cdot}2515 :: 100{\cdot}0000 :$) 12·0906 pounds. Consequently the pound of

the combustible portion of "Nixon's navigation coal" was intrinsically $\left(\frac{12{\cdot}7519 - 12{\cdot}0906 \times 100}{12{\cdot}0906} = \right)$ 5·47 per centum superior in water vaporizative power to the pound of the combustible portion of the Cumberland semi-bituminous coal. That is to say, if both coals had the same percentage and kind of refuse such would be their relative value in water heating effect. This difference may very easily be allowed.

The very great difference in the water vaporizative power of equal weights of the two crude coals prevents their use for measuring the economic performances of the machinery in the two cases.

THE WEARING POWER OF STEEL RAILS IN RELATION TO THEIR CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES.*

By Charles B. Dudley, Ph.D., Chemist Pennsylvania Railroad Company, Altoona, Pa.

Read at the Philadelphia Meeting of the American Institute of Mining Engineers, held at the Franklin Institute, February 17, 1881.

Theo. N. Ely, Esq., Superintendent of Motive Power, Pennsylvania Railroad.

Dear Sir—It is now nearly three years since my first report to you on the subject of steel rails was written. That report, as you will

* At the Lake George meeting of the Institute in October, 1878, I had the honor of presenting to the Institute, through the kind permission of the officers of the Pennsylvania Railroad Company, the results of a study of twenty-five examples of steel rails, which had all been in actual service. Considerable discussion followed the publication of that paper, and there seemed to be a strong disinclination, especially on the part of the steel rail manufacturers, to accept the conclusions presented. One of the principal objections urged against the conclusions drawn was that they were based on too few samples; in other words, that no conclusions safe to act upon could be drawn from the examination of twenty-five rails. In view of this criticism it was decided to repeat the investigation with a larger number of samples, and with the aid of the experience gained in the first investigation. The results of this second study of steel rails are, by the permission of the officers of the Pennsylvania Railroad Company, herewith presented to the Institute, with the sincere desire that they may aid in adding to our knowledge of this most important product. Like the previous paper, this is in the form of a report to one of the officers of the company, which will account for the style, and the manner of presenting the data.

remember, dealt principally with the question of the relation between the chemical composition and physical properties of steel rails and their power to resist crushing and fracture in actual service. Other matters were referred to or touched upon in that report, but the main question was, Why do some rails crush or break in service while others do not? You will doubtless remember that the principal conclusion arrived at was, that the softer rails are less liable to crush or break in service than the hard ones. Or, in other words, so far as conclusions could be drawn from the chemical analysis and physical test of 25 samples of steel rails which had actually been in service, these conclusions were that those rails which have the smaller amounts of carbon, phosphorus, silicon and manganese are less liable to crush or break in service than those which have larger amounts of these elements. Or, again, looked at in the light of physical tests, those rails which have the lower tensile strength and the greater elongation are the ones which give the least trouble from breaking or crushing in track.

In the report just referred to, the question of the wearing power of steel rails was not made prominent, and from that report no positive and definite information could be obtained as to what quality of steel would give rails that would endure the greatest amount of traffic with the least loss of metal. And yet, of the three principal causes which occasion the removal of rails from the track, viz., broken, crushed and worn out, perhaps the latter is of the most importance. With the improvement in maintenance of way which has characterized the Pennsylvania Railroad during the last five or six years, the removal of rails from track from the first two of these causes has, if I am right, quite notably diminshed. This certainly is true with regard to broken rails. And if, as time advances, the number of crushed rails shall diminish, both because of the continued improvement in maintenance of way, before referred to, and because, owing to improved and better methods at the steel works, there are fewer crushed rails caused by physical defects in the steel, the question of the wearing power of steel rails obviously becomes the all-important one. In view of these considerations, it was thought that an investigation into the relation between the wearing power of steel rails and their chemical composition and physical properties could not fail to throw light upon a question of vital importance in the management of the Pennsylvania Railroad. The results of such an investigation are presented in the

following report, which deals not, as did the previous report, with the relations between the chemical and physical characteristics of steel rails and their power to resist crushing or fracture, but entirely with the relation between these characteristics and wear.

On any railroad the rails are or may be called upon to perform their service under quite varying conditions. On a railroad like the Pennsylvania Railroad, for example, there are levels and grades, and there are tangents and curves, and there are combinations of the levels and grades with the tangents and curves. Moreover, the rails on the high sides of curves do their service under different conditions from those on the low sides of curves. So that, as far as kind of service is concerned, a rail may be called upon to do its work under one of these six conditions, viz., on level tangent, on high side of level curve, on low side of level curve, on grade tangent, on high side of grade curve, or on low side of grade curve. Any investigation, therefore, into the wearing power of steel rails, which shall be of service in determining what rails are best for the whole road, must take into account these six conditions. Of course there are many different grades and curves of different radius on the Pennsylvania Railroad; but to study wear on each grade, and for every radius of curvature, would make a problem almost life-long. In order, therefore, to make the work manageable it becomes necessary to choose some average grade and some medium degree of curvature, as representing the different grades and curves on the road. This has been done in the work about to be described.

Now, the problem before us is: What chemical composition and what physical properties are characteristic of those rails which in actual service have lost least metal in proportion to the tonnage that has passed over them? In order to get the information necessary to answer this question, 64 rails were taken from the track in July, 1879, and subjected to chemical analysis and physical test, as is detailed further on. Sixteen of these rails were taken from level tangents and 16 from level curves, 8 from the high side and 8 from the low side of the curves. Again, 16 rails were taken from grade tangents and 16 from grade curves, 8 from the high side and 8 from the low side of these curves. The 32 rails on grades were all taken between Conemaugh and Altoona, and the 32 on levels between Tyrone and Mifflin. Furthermore, 32 of the rails were taken from the north track, and 32 from the south track. The principle governing the selection was to

secure 8 as slow-wearing rails and 8 as rapid-wearing rails as could be found on each of the four conditions of service—level tangents, level curves, grade tangents and grade curves—the rails on curves being taken, as has been already described, one-half from the high side of the curve and one-half from the low side of the curve. In the actual selection a pair of callipers was used, and the loss in height of a rail, compared with its time of service, gave a sufficiently accurate measure of the rate of wear of a rail to determine its selection. It should be stated here that since the rails were selected in July, after the usual annual removal from the track of worn-out rails, which takes place earlier in the season, the more rapid-wearing rails obtained for examination are not as marked examples of rapid-wearing rails as would have been obtained had the selection been earlier made. With regard to the 64 rails chosen, it may also be stated that not one of them had broken in service, and only one showed any signs of crushing; so that, as far as every quality is concerned, except their rate of wear, all of them might be classed as good rails.

It was thought that a chemical examination and physical test of the 64 rails, compared with the loss of metal they had suffered by the tonnage which had passed over them, could not fail to throw some light on the question as to what kind of steel in rails gives best wear. These rails having been selected were removed from the track and sent to Altoona. They were then cleaned and weighed on an ordinary platform scale, their length measured as accurately as possible with a steel tape, and their height callipered near both ends and in the middle. The weight of the whole rail divided by its length obviously gives the present weight per yard of these worn rails. The weights obtained in this manner, however, were not subsequently used, as will be explained further on. After the weighing, five feet were cut off from the end of each rail for test purposes. The test-pieces, except those used in the bending test, were all cut from the head of the rail. Two pieces for tensile test, two for torsion test, and two pieces from the web for bending test, as well as a section of the rail $\frac{1}{2}$ inch thick, were taken from each rail. The tensile test-pieces were 15 inches long, with a reduced section $\frac{3}{4}$ inch in diameter, and 5 inches between shoulders. They also had a groove just beyond each end of the reduced section for holding the micrometer arrangement used in determining the elastic limit. The torsion test-pieces were of the usual size, 4 inches long and 1 inch square, with a reduced section $\frac{5}{8}$ inch in diam-

eter, and 1 inch between shoulders, with a $\frac{1}{8}$ inch fillet. For the shearing test one-half of the tensile test-pieces, after they were broken, was turned down to a rod $\frac{5}{8}$ inch in diameter, and sheared off (single shear) in a shearing apparatus prepared for the purpose. For the bending test two pieces $1\frac{1}{2}$ inches wide, and 12 inches long, were slotted out of the web of each rail. Accompanying Plate 1 gives the details of the form and size of the test-pieces and of the shearing apparatus. A and B represent the shearing apparatus, full size; C represents the tensile test-piece, half size; D, the torsion piece, full size; E, the shearing piece, full size; and F, the bending test-piece, half size. The half-inch section of each rail was used in determining the present weight per yard of the worn rails, the original weight per yard of these rails when laid, as will be described further on, and also in making the diagrams of the worn rails, which appear in the accompanying Plates 2, 3, 4 and 5.

When the tensile test-pieces had been prepared, one-half of them were annealed by heating them to a fair red heat, and then allowing them to cool slowly for 36 hours. Both the annealed and the unannealed test-pieces were then tested in the tensile testing-machine. In determining the elastic limit yokes were fitted to the grooves in the test-pieces prepared for them, which yokes carried micrometer screws on opposite sides of the pieces, reading to the ten thousandth of an inch, and fitted up for electrical contact. The pieces were then strained with successive loads, increasing by 2000 pounds per square inch. After the application of each load the elongation was measured by the micrometers, and the point at which the elongation ceased to be directly proportioned to the load was regarded as the elastic limit. The results of these tests are given on Plates 6 and 7. The figures as to tensile strength and elastic limit mean pounds per square inch. The elongation is per cent. in five inches. Neither of the torsion test-pieces were annealed, they being tested in the condition in which the steel was when removed from the track. The diagrams made by the test of these pieces were measured up, and the results are given in connection with the results of the tensile tests as above described. The figures given as to length of diagram, height of diagram, and elastic limit are in inches and hundredths of an inch; and those giving areas of diagram are square inches. They are the mean of the results from the two test-pieces. In the shearing tests the figures given under "shearing stress" are pounds per square inch; while the "detrusion"

before rupture represents the travel or motion of the shearing piece A, in Plate 1, measured in decimals of an inch. In making these measurements a load of 2000 pounds was put on the pieces and then a reading made; at the moment of rupture another reading was made. The difference of these two readings represents the detrusion. In making the bending tests, the pieces before described were supported on knife edges 10 inches apart, and bent by a third knife edge at equal distances from the supports, after the manner of making transverse tests of metal. In making these tests it was found that the load applied gradually increased until it reached a maximum, and then diminished slowly. The deflection obtained at the point of maximum load varied considerably in the different rails, being a half inch or more each side of two inches. After the maximum load had been obtained as above described, the pieces were removed from the strain, and set up on end in the same machine, and then bent until rupture took place or until they could be bent down no farther. The broken or bent pieces were then laid on a piece of paper in the position in which they were at rupture or as bent, and the amount of deflection from a straight line of the piece broken or bent was measured with a protractor. The figures given under the head "bending tests" are maximum load and deflection. The maximum load was calculated from the data obtained in testing the pieces, for a piece $1\frac{1}{2}$ inches wide and $\frac{1}{2}$ inch thick. The deflection is in degrees. In all cases where the deflection is given as 190°, the pieces did not break, but had the form when removed from the machine of a letter U with the ends brought together until they formed with each other an angle of 10°.

From the torsion test-pieces after they were broken borings were taken for analysis. In these borings the carbon, phosphorus, silicon and manganese were determined. All the chemical work was done in duplicate. The carbon was determined, after separation from the iron by chloride of copper and ammonium, by combustion in oxygen gas, the phosphorus by the molybdate method, the manganese by the bromine method, and the silicon in the usual manner. The result of these determinations are given with the other data. So much for the methods of the chemical and physical testing of these rails.

In determining the rate of wear of a steel rail it is of course necessary to know the loss of metal per yard which each rail has suffered and the tonnage. The loss of metal per yard divided by the tonnage

gives the rate of wear; and when this datum is obtained for a series of rails, it furnishes a means of comparison as to their wearing power.

The tonnage of the 64 rails we are studying was computed from the data as to number of trains and movement of cars in the office of the superintendent of transportation, Mr. John Reilly. These data were twice worked over, and while I do not think that the tonnages given with each rail are absolutely the number of tons which have passed over them, I do think that the percentage error is small, and that the comparison of one rail with another by means of these tonnages, which is really what we are after, gives results that can safely be relied on.

With regard to the loss of metal per yard and the method by which it was obtained it will be necessary to go a little into detail. Of course nothing could be simpler than to obtain the loss of metal per yard of these rails, provided the data were at hand, for this is simply the difference between the present weight per yard of the worn rails and the original weight per yard of these rails when they were laid. But, unfortunately, these rails were not weighed when they were put in track, and so one essential element of our data is wanting. Nor will it do to assume that these rails originally weighed 67 lbs. or 56 lbs. per yard, which is the standard weight of the different rails embraced in this series. Mr. J. W. Cloud, engineer of tests, finds by the weight of a number of new rails just from the mills, weighed at Altoona during two or three years past, that they vary from $\frac{1}{2}$ lb. to $1\frac{1}{2}$ lbs. per yard from standard weight. Still further, an examination of the rails in our series shows that some of them, from the web being thinner than standard, which means that the rolls were closer together when that rail was rolled, could not have weighed when new more than 64 lbs. or 65 lbs. per yard.

In view of these statements, the question fairly meets us: How can the loss of metal per yard of these rails be determined? It is evident to all, I think, that if we know the weight per yard of these worn rails, and then are able to obtain the areas (1) of a section of the worn rail, and (2) of a section of the original rail as rolled, we have at hand all the data necessary for obtaining the weight per yard of the rail as rolled. For it is clear, I am sure, that as the area of a section of the worn rail is to its weight per yard so is the area of a section of the original rail to its weight per yard. If, therefore, we can obtain (1) the weight per yard of the worn rails, (2) the area of a

section of each of these rails, and (3) the area of a section of each rail as rolled, we shall be able to obtain the loss of metal per yard of each of the rails in the series we are studying. Can these data then be obtained?

First, as to the areas. How can the area of a section of the worn rail and of a section of the rail as rolled be obtained? The following was the method used. The half-inch section of the worn rails before referred to was laid upon a sheet of paper, and its outline traced upon the paper with the utmost care by means of a very sharp-pointed hard pencil. The surface inclosed within this tracing corresponds very closely with the section of the worn rail. Then directly over this tracing was laid the template of the section after which this rail was rolled, and a tracing then made with a sharp-pointed hard pencil as before of that portion of the head which was lacking in the worn rail. If now the original height of the rail was the same as the template used, and if the original shape of the head of the rail was that of the template, we have in this manner a diagram on paper representing a section of the worn rail, and also one representing a section of the original rail as rolled. The diagrams obtained in this manner for each rail in the series are represented in accompanying Plates 2, 3, 4 and 5. The areas of these diagrams were then obtained by means of the planimeter.

What now are the assumptions, and what are the probable errors in this method? The first assumption is that the original rails as rolled were the same height as the template. This is probably not exactly true in fact. The wear of the rolls, and possibly carelessness in making the rolls originally, together with the fact that the rails rolled in the same set of rolls were probably not all rolled at the same temperature, and consequently shrunk different amounts in cooling, might each occasion small deviations from the height which the rail should have according to template. And yet Mr. Cloud, engineer of tests, has callipered the height of some 60 new rails here at Altoona during the year past, which rails were from different mills, and has found the variation from standard height not more than $\frac{1}{100}$ of an inch. It would seem, therefore, that the error arising from the assumption as to height of rail could not be large.

The second assumption is that the original shape of the top of the head of the rails we are studying was that of the template. This is of course a question of accuracy in the original manufacture of the

rolls, and of their wear. Now it is impossible to say how accurately the rolls were originally made, and how much they have worn out of shape when any rail was rolled. But in any case the error must be very small, for any noteworthy deviation of the top of the head from standard would have given difficulty in securing a straight, even track, and would have caused the rejection of those rails by the inspector at the mills.

The third assumption is that these rails have not suffered distortion as to height by the service which they have endured. Upon this point I will say that I think an inspection of the diagrams in accompanying Plates 2, 3, 4 and 5 will convince any one that this distortion, if any, is excessively small. It should be stated here that any deviation of these rails from template, such as beading over on one side of the head, or thicker or thinner webs than standard, or variation in the shape of the foot or in the under side of the head, can cause no error; because in taking the areas with the planimeter, the diagrams from which the area of the worn section and the area of the original section were taken, coincide in every part except in that part of the original section which was traced-in from template as above described. In other words, in getting the areas of the rails as rolled, the actual section of the rail just as it was rolled was used in every part, except that portion of the head which was gone from wear, which portion was restored from template.

Fourth. How accurately can the areas be obtained by means of the planimeter? The planimeter which was used gave readings to $\frac{1}{100}$ of a square inch. If, therefore, the manipulation was such as to give the instrument its full chance, the maximum error in area could not be over $\frac{1}{100}$ of a square inch. As a matter of fact, in taking the areas with the planimeter, from three to five measurements were made of each diagram, which measurements differed from each other not more than from one to three hundredths of an inch, and then a mean of these measurements was taken as representing the area of the diagram. It seems probable, therefore, that the error arising from this cause could not in any case amount to more than one or two hundreths of a square inch.

Now as to the weight per yard of the worn rails. How can this best be obtained? Obviously the most simple method would be to weigh each of the worn rails, and then divide the weight by the length. This was done with these rails, as has already been mentioned. But

when the results were obtained, and the original weight of the rails computed, by means of the areas as above described, it was found that some rails rolled at the same mill, at the same time, and with the same thickness of web and same shape of foot, differed from each other in the original weight, as computed, from 1½ to 3 lbs. per yard. The explanation of this seems to be that the half-inch sections before referred to, which were used in getting the areas, did not exactly represent the whole rail; in other words, the rail was unevenly worn. This explanation was confirmed by callipering the height of the half-inch sections, and comparing these heights with the heights of the rail in different places. It became necessary, therefore, to devise some other means of obtaining the weight per yard of the worn rails, and it was finally decided to obtain the desired weights from the half-inch sections themselves before referred to. These sections were all, therefore, carefully weighed on a balance which weighed accurately to one-half a grain. If, now, the half-inch sections were exactly half an inch in thickness, a little consideration shows that it is possible in this way to get at the weight of a rail more accurately than it could be obtained by weighing the whole rail on a common platform scale, supposing, of course, that the rail was uniform in section throughout its length. For there are 72 half-inch sections in a yard, and in a 30-foot rail 720 half-inch sections. If, now, the error in weighing a half-inch section is one-half a grain, the total error in the weight of a 30-foot rail would be 720 half grains, or 360 grains, which is a little less than an ounce. Inasmuch, therefore, as ordinary platform scales do not generally weigh closer than half a pound, it is evident that, so far as accuracy of weighing is concerned, the method of getting at the weight per yard of these worn rails, by weighing the half-inch sections, leaves nothing to be desired.

But were these half-inch sections exactly half an inch thick? An examination of these sections by means of vernier callipers, reading to one-thousandth of an inch, showed that they were not exactly half an inch thick, and that they varied in thickness in different parts of the section. The reasons for this seem to be, that it is almost impossible to set a tool so as to cut off exactly half an inch from a rail, and that in cutting steel as hard as some of these rails were, the tool is apt to spring more or less, and thus give a section of varying thickness. It became necessary, therefore, to devise some method by means of which the average thickness of these sections could be obtained. This was

done as follows: The half-inch sections were all carefully weighed in distilled water, at a temperature of 66°F., on a balance weighing to half a grain. The difference between the weight so obtained and the weight of the same sections in air gives the weight of a volume of water equal to the volume of the section. Now, this weight of water divided by the weight of a cubic inch of water, which was taken as 252·5 grains, gives the volume of space occupied by any section. This volume being known, it is of course only necessary to divide the same by the area obtained by the planimeter, as before described, and the result is the average thickness of each section; and the weight and thickness of each section being known, a very simple calculation gives us the weight per yard, corresponding to each of the worn rails which we are dealing with.

Now, what are the possible errors involved in this method? As to the weight in air of the half-inch sections, it has already been shown that an error of half a grain in the weight of each section gives an error per yard that can safely be ignored. An error of half a grain in weighing the sections in water gives an error in the weight per yard of the worn rail of ·05 of a pound; and an error of a hundredth of a square inch in taking the areas of the sections with the planimeter causes an error in the weights of about a tenth of a pound. It seems fair, therefore, to conclude that probably the weights of the worn rails and of these rails when originally laid, as obtained in the manner above described, do not differ from the true weights more than possibly a quarter of a pound per yard.

It is, of course, to be confessed that whatever errors there may be, either in the weight of the worn rails or in the original weight of these same rails, appears in the loss of metal due to wear—which is really what we are after—and which is simply the difference between these two weights. But it must be remembered that, in determining the value of a rail, this loss of metal is subsequently divided by the tonnage, and consequently the influence of the error is thereby very greatly diminished. And while there may be a few rails in the series which occupy a place which they would not occupy if the loss of metal were more accurately known, yet I think these cases are too few to seriously obscure or counteract the general conclusions which the results that have been obtained are calculated to teach.

In the following pages are given the history of each rail and the tonnage. The essential parts of this history, together with the ton-

nage, the chemical analyses, the weights per yard, and loss of metal, as well as the loss per million tons, and the complete results of the physical tests and the density, are given in tabular form in accompanying Plates 6 and 7. These tables will be discussed farther on. The density is the weight of a cubic inch of the steel. This weight was obtained by dividing the weight of each of the half-inch sections by its volume, the data for this purpose having been obtained as previously described. The figures given under density are fractions of a pound.

In looking over the original weights of the rails as obtained, it will doubtless be observed that, although these rails were all supposed to have weighed 67 lbs. or 56 lbs. per yard when rolled, the figures given differ both ways from these figures. These differences are principally to be accounted for by differences in the shape of the bases and differences in the thickness of the webs. With regard to the latter point, it is evident that of two rails rolled at the same mill, in the same year, if one has a web three or five one-hundredths of an inch thicker than another—which means that the rolls were farther apart when the thick-web rail was rolled—the thin-web rail will be lighter than the other. The thickness of the webs of all the rails in the series we are studying was carefully measured with vernier callipers, and the differences from the standard thickness were found to vary both ways, from nothing up to five one-hundreths of an inch thinner than standard, and seven one-hundredths thicker than standard. Finally, the differences in the density of the different rails still further helps us to account for the differences in weight per yard of the rails as rolled.

The following is the history and tonnage of the different rails:

No. 881. Steel of 1868. Was on tangent, north rail, north track, in Bennington Cut. In service from June, 1868, to July, 1879—11 yrs. 1 mo. Grade, 92·4 ft. to the mile. Tonnage, 55,546,811 tons.

No. 882. Steel of 1868. Was on tangent, north rail, north track, in Bennington Cut. In service from June, 1868, to July, 1879—11 yrs. 1 mo. Grade, 92·4 ft. to the mile. Tonnage, 55,546,811 tons.

No. 883. Steel of 1869. Was on tangent, north rail, north track, on Whip-poor-will Straight. In service from May, 1869, to July,

1879—10 yrs. 2 mos. Grade, 95·04 ft. to the mile. Tonnage, 52,174,969 tons.

No. 884. Steel of 1869. Was on tangent, north rail, north track, on Whip-poor-will Straight. In service from May, 1869, to July, 1879—10 yrs. 2 mos. Grade, 95·04 ft. to the mile. Tonnage, 52,174,969 tons.

No. 885. Steel of 1868. Was on tangent, south rail, north track, just west of Allegrippus Station. In service from July, 1868, to July, 1879—11 yrs. Grade, 89·76 ft. to the mile. Tonnage, 55,197,994 tons.

No. 886. Steel of 1868. Was on tangent, north rail, north track, just west of Allegrippus Station. In service from July, 1868, to July, 1879—11 yrs. Grade, 89·76 ft. to the mile. Tonnage, 55,197,994 tons.

No. 887. Steel of 1868. Was on tangent, south rail, north track, west of Allegrippus Station. In service from July, 1868, to July, 1879—11 years. Grade, 89·76 ft. to the mile. Tonnage, 55,197,994 tons.

No. 888. Steel of 1868. Was on tangent, south rail, north track, west of Allegrippus Station. In service from July, 1868, to July, 1879—11 years. Grade, 89·76 ft. to the mile. Tonnage, 55,197,994 tons.

No. 889. Steel of 1873. Was on tangent, south rail, south track, at South Fork. In service from August, 1873, to July, 1879—5 yrs. 11 mos. Grade, 21·13 ft. to the mile. Tonnage 44,620,100 tons.

No. 890. Steel of 1873. Was on tangent, north rail, south track, at South Fork. In service from August, 1873, to July, 1879—5 yrs. 11 mos. Grade, 21·13 ft. to the mile. Tonnage, 44,620,100 tons.

No. 891. Steel of 1872. Was on tangent, south rail, south track, at Summer Hill water plug. In service from June, 1872, to July, 1879—7 yrs. 1 mo. Grade, 40·13 ft. to the mile. Tonnage, 53,687,-192 tons.

No. 892. Steel of 1872. Was on tangent, south rail, south track, at Summer Hill water plug. In service from June, 1872, to July, 1879—7 yrs. 1 mo. Grade, 40·13 ft. to the mile. Tonnage, 53,687,-192 tons.

No. 893. Steel of 1874. Was on tangent, north rail, south track,

near Summer Hill. In service from May, 1874, to July, 1879—5 yrs. 2 mos. Grade, 21·12 ft. to the mile. Tonnage, 38,088,572 tons.

No. 894. Steel of 1874. Was on tangent, south rail, south track, east of Portage. In service from May, 1874, to July, 1879—5 yrs. 2 mos. Grade, 52·8 ft. to the mile. Tonnage, 38,088,572 tons.

No. 895. Steel of 1874. Was on tangent, south rail, south track, east of Portage. In service from May, 1874, to July, 1879—5 yrs. 2 mos. Grade, 52·8 ft. to the mile. Tonnage, 38,088,572 tons.

No. 896. Steel of 1874. Was on tangent, south rail, south track, east of Portage. In service from May, 1874, to July, 1879—5 yrs. 2 mos. Grade, 52·8 ft. to the mile. Tonnage, 38,088,572 tons.

No. 897. Steel of 1868. Was on high side of 5° curve, north rail, north track, east of Bridge No. 3, Summer Hill. In service from May, 1868, to July, 1879,—11 yrs. 2 mos. Grade, 21·12 ft. to the mile. Tonnage, 52,370,617 tons.

No. 898. Steel of 1868. Was on high side of 5° curve, north rail, north track, east of Bridge No. 3, Summer Hill. In service from May, 1868, to July, 1879—11 yrs. 2 mos. Grade, 21·12 ft. to the mile. Tonnage, 52,370,617 tons.

No. 899. Steel of 1868. Was on low side of 5° curve, south rail, north track, east of bridge No. 3, Summer Hill. In service from May, 1868, to July, 1879—11 yrs. 2 mos. Grade, 21·12 ft. to the mile. Tonnage, 52,370,617 tons.

No. 900. Steel of 1868. Was on low side of 5° curve, north rail, north track, east of Bridge No. 3, Summer Hill. In service from May, 1868, to July, 1879—11 yrs. 2 mos. Grade, 21·12 ft. to the mile. Tonnage, 52,370,617 tons.

No. 901. Steel of 1871. Was on low side of 5° curve, south rail, north track, in Gable's Cut, near Summer Hill. In service from August, 1871, to July, 1879—7 yrs. 11 mos. Grade, 39·6 ft. to the mile. Tonnage, 40,061,230 tons.

No. 902. Steel of 1871. Was on high side of 5° curve, north rail, north track, in Gable's Cut, near Summer Hill. In service from August, 1871, to July, 1879—7 yrs. 11 mos. Grade, 39·6 ft. to the mile. Tonnage, 40,061,230 tons.

No. 903. Steel of 1876. Was on high side of 5° curve, south rail, south track, west of Bridge No. 1, Summer Hill. In service from

August, 1876, to July, 1879—2 yrs. 11 mos. Grade, 39·6 ft. to the mile. Tonnage, 21,504,824 tons.

No. 904. Steel of 1876. Was on low side of 5° curve, north rail, south track, west of bridge No. 1, near Summer Hill. In service from August, 1876, to July, 1879—2 yrs. 11 mos. Grade, 39·6 ft. to the mile. Tonnage, 21,504,824 tons.

No. 905. Steel of 1868. Was on high side of 5° curve, north rail, north track, east end of Milmore Middle Siding. In service from June, 1868, to April, 1879—10 yrs. 10 mos. Grade, 47·52 ft. to the mile. Tonnage, 50,648,939 tons.

No. 906. Steel of 1868. Was on low side of 5° curve, south rail, north track, east end of Wilmore Middle Siding. In service from June, 1868, to April, 1879—10 yrs. 10 mos. Grade, 47·52 ft. to the mile. Tonnage, 50,648,939 tons.

No. 907. Steel of 1874. Was on high side of 5° curve, north rail, north track, east of Wilmore Middle Siding. In service from June, 1874, to April, 1879—4 yrs. 10 mos. Grade, 47·52 ft. to the mile. Tonnage, 24,211,147 tons.

No. 908. Steel of 1875. Was on low side of 4° curve, north rail, south track, near tower at east end of Galitzin Tunnel. In service from May, 1875, to July, 1879—4 yrs. 2 mos. Grade, 95·04 feet to the mile. Tonnage, 32,428,614 tons.

No. 909. Steel of 1875. Was on high side of 4° curve, south rail, south track, near tower at east end of Galitzin Tunnel. In service from May, 1875, to July, 1879—4 yrs. 2 mos. Grade, 95·04 ft. to the mile. Tonnage, 32,428,614 tons.

No. 910. Steel of 1871. Was on low side of 5° curve, south rail, south track, west of Allegrippus Station. In service from July, 1871, to July, 1879—8 yrs. Grade, 89·76 ft. to the mile. Tonnage, 62,813,664 tons.

No. 911. Steel of 1877. Was on low side of 5° curve, south rail, south track, second curve west of Allegrippus Tower. In service from April, 1877, to July, 1879—2 yrs. 3 mos. Grade, 89·76 ft. to the mile. Tonnage, 17,226,993 tons.

No. 912. Steel of 1873. Was on high side of 5° curve, north rail, south track, second curve west of Allegrippus Tower. In service from July, 1873, to July, 1879—6 yrs. Grade, 89·76 ft. to the mile. Tonnage, 47,438,145 tons.

No. 913. Steel of 1870. Was on tangent, north rail, north track,

600 feet west of mile post 211 from Philadelphia. In service from March, 1870, to July, 1879—9 yrs. 4 mos. On level. Tonnage, 45,855,101 tons.

No. 914. Steel of 1870. Was on tangent, south rail, north track, 600 feet west of mile post 211 from Philadelphia. In service from March, 1870, to July, 1879—9 yrs. 4 mos. On level. Tonnage, 45,855,101 tons.

No. 915. Steel of 1873. Was on tangent, south rail, north track, east of Petersburg Toolhouse. In service from June, 1873, to July, 1879—6 yrs. 1 mo. On level. Tonnage, 31,514,889 tons.

No. 916. Steel of 1873. Was on tangent, north rail, north track, just west of Ardenheim. In service from July, 1873, to July, 1879—6 yrs. On level. Tonnage, 31,127,829 tons.

No. 917. Steel of 1873. Was on tangent, south rail, north track, just west of Ardenheim. In service from July, 1873, to July, 1879—6 yrs. On level. Tonnage, 31,127,829 tons.

No. 918. Steel of 1869. Was on tangent, north rail, north track, west of Vandevaner's Bridge. In service from January, 1869, to July, 1879—10 yrs. 6 mos. On level. Tonnage, 51,720,011 tons.

No. 919. Steel of 1869. Was on tangent, north rail, north track, west of Vandevaner's Bridge. In service from January, 1869, to July, 1879—10 yrs. 6 mos. On level. Tonnage, 51,720,011 tons.

No. 920. Steel of 1867. Was on tangent, south rail, north track, at Jackstown Water-trough. In service from December, 1867, to July, 1879—11 yrs. 7 mos. On level. Tonnage, 52,991,684 tons.

No. 921. Steel of 1874. Was on tangent, north rail, north track, 200 feet east of mile post 211 from Philadelphia. In service from March, 1874, to July, 1879—5 yrs. 4 mos. On level. Tonnage, 27,622,230 tons.

No. 922. Steel of 1874. Was on tangent, south rail, north track, 200 ft. east of mile post 211 from Philadelphia. In service from March, 1874, to July, 1879—5 yrs. 4 mos. On level. Tonnage, 27,622,230 tons.

No. 923. Steel of 1873. Was on tangent, south rail, north track, east of Petersburg Toolhouse. In service from June, 1873, to July, 1879—6 yrs. 1 mo. On level. Tonnage, 31,514,889 tons.

No. 924. Steel of 1875. Was on tangent, south rail, south track, west of Vandevaner's Bridge. In service from June, 1875, to July, 1879—4 yrs. 1 mo. On level. Tonnage, 36,349,989 tons.

No. 925. Steel of 1875. Was on tangent, south rail, south track, west of Vandevaner's Bridge. In service from June, 1875, to July, 1879—4 yrs. 1 mo. On level. Tonnage, 36,349,989 tons.

No. 926. Steel of 1870. Was on tangent, south rail, south track, 1500 feet west of mile post 182 from Philadelphia. In service from April, 1870, to July, 1879—9 yrs. 3 mos. On level. Tonnage, 76,409,123 tons.

No. 927. Steel of 1870. Was on tangent, south rail, south track, 1500 feet west of mile post 182 from Philadelphia. In service from April, 1870, to July, 1879—9 yrs. 3 mos. On level. Tonnage, 76,409,123 tons.

No. 928. Steel of 1874. Was on tangent, south rail, south track, 200 feet east of mile post 181 from Philadelphia. In service from July, 1874, to July, 1879—5 yrs. On level. Tonnage, 43,610,150 tons.

No. 929. Steel of 1867. Was on high side of $2\frac{1}{4}°$ curve, north rail, north track, 250 feet east of mile post 194 from Philadelphia. In service from December, 1867, to July, 1879—11 yrs. 7 mos. On level. Tonnage, 52,991,684 tons.

No. 930. Steel of 1867. Was on low side of $2\frac{1}{4}°$ curve, south rail, north track, 250 feet east of mile post 194 from Philadelphia. In service from December, 1867, to July, 1879—11 yrs. 7 mos. On level. Tonnage, 52,991,684 tons.

No. 931. Steel of 1868. Was on high side of 3° curve, south rail, north track, 400 feet east of mile post 191 from Philadelphia. In service from January, 1869, to July, 1879—10 yrs. 6 mos. On level. Tonnage, 51,720,011 tons.

No. 932. Steel of 1868. Was on low side of 3° curve, north rail, north track, 400 feet east of mile post 191 from Philadelphia. In service from January, 1869, to July, 1879—10 yrs. 6 mos. On level. Tonnage, 51,720,011 tons.

No. 933. Steel of 1869. Was on high side of $3\frac{1}{2}°$ curve, north rail, south track, 1000 feet east of mile post 183 from Philadelphia. In service from November, 1869, to July, 1879—9 yrs. 8 mos. On level. Tonnage, 78,364,968 tons.

No. 934. Steel of 1869. Was on low side of $3\frac{1}{2}°$ curve, south rail, south track, 1000 feet east of mile post 183 from Philadelphia. In service from November, 1869, to July, 1879—9 yrs. 8 mos. On level. Tonnage, 78,364,968 tons.

No. 935. Steel of 1866. Was on high side of 2° curve, north rail, south track, at McVeytown Station. In service from September, 1866, to June, 1879—12 yrs. 9 mos. On level. Tonnage, 92,025,478 tons.

No. 936. Steel of 1866. Was on low side of 2° curve, south rail, south track, at McVeytown Station. In service from September, 1866, to June, 1879—12 yrs. 9 mos. On level. Tonnage, 92,025,478 tons.

No. 937. Steel of 1876. Was on low side of 2° curve, south rail, south track, 200 feet west of mile post 192 from Philadelphia. In service from March, 1876, to July, 1879—3 yrs. 4 mos. On level. Tonnage, 29,905,122 tons.

No. 938. Steel of 1876. Was on high side of 2° curve, north rail, south track, 200 feet west of mile post 192 from Philadelphia. In service from March, 1876, to July, 1879—3 yrs. 4 mos. On level. Tonnage, 29,905,122 tons.

No. 939. Steel of 1875. Was on the low side of 4° curve, south rail, south track, 250 feet east of Mount Union Bridge. In service from May, 1875, to July, 1879—4 yrs. 2 mos. On level. Tonnage, 37,150,179 tons.

No. 940. Steel of 1875. Was on the high side of 4° curve, north rail, south track, 250 feet east of Mount Union Bridge. In service from May, 1875, to July, 1879—4 yrs. 2 mos. On level. Tonnage, 37,150,179 tons.

No. 941. Steel of 1874. Was on high side of 3° curve, south rail, south track, 300 feet east of Manayunk. In service from September, 1874 to July, 1879—4 yrs. 10 mos. On level. Tonnage, 42,277,638 tons.

No. 942. Steel of 1874. Was on low side of 3° curve, north rail, south track, 300 feet east of Manayunk. In service from September, 1874, to July, 1879—4 yrs. 10 mos. On level. Tonnage, 42,277,638 tons.

No. 943. Steel of 1873. Was on the low side of 2° curve, south rail, south track, 2000 feet west of mile post 179 from Philadelphia. In service from April, 1873, to July, 1879—6 yrs. 3 mos. On level. Tonnage, 55,127,464 tons.

No. 944. Steel of 1873. Was on high side of 2° curve, north rail, south track, 2000 feet west of mile post 179 from Philadelphia. In

service from April, 1873, to July, 1879—6 yrs. 3 mos. On level. Tonnage, 55,127,464 tons.

Accompanying Plates 6 and 7 give in tabular form all the essential data of the history of the rails, together with the chemical analyses, weights, and results of the chemical tests, as has been before stated. To a study of these tables attention is now directed. As will be observed, the rails have been arranged in six groups, according to the kind of service to which they have been subjected. The first group of 16 rails did their service on grade tangents; the second group of 8 rails on the low side of grade curves; the third group of 8 rails on the high side of grade curves; the fourth group of 16 rails on level tangents; the fifth group of 8 rails on the low side of level curves; and the sixth group of 8 rails on the high side of level curves. As will likewise be observed, the rails within the groups have been arranged in regular order according to loss of metal per million tons, the rail having lost least metal per million tons being placed first. The first rails in the several groups are therefore the slower wearing, while the latter rails are the more rapid wearing. This arrangement enables us to compare the slower-wearing rails of the different kinds of service with the more rapid-wearing ones, and to discover what physical qualities, and what chemical composition, are characteristic of the slower-wearing as well as the faster-wearing rails.

Giving our attention now to the tables, I think the first observation will be that there is no absolute gradation in physical qualities, or in chemical composition, applying to every rail in each group, which corresponds to the gradation in amount of metal lost per million tons. In other words, if we take tensile strength, or elongation in the physical qualities, or the carbon or phosphorus in the chemical composition, we do not find that the first rail in each group is characterized by a certain figure in any one or more of these respects, while the last rail in the group is characterized by another different figure, and all the intermediate rails arrange themselves in respect to any of these peculiarities, between these two extreme rails of the group. Nor do I think we ought to expect such uniformity, and for the following reasons:

First. Whatever errors there may have been in determining the loss of metal of these rails or in the tonnages, as has been before described, will of course have an influence in determining the position

of any rail in the group to which it belongs. And, as has already been said, while I do not think that these errors, whatever they may be, are sufficient to seriously obscure or counteract the general conclusions which the results are calculated to teach, yet these errors may possibly be large enough to give some rail a position in the group which it should not occupy.

Second. I am not aware that it is known as yet exactly what *wear* is, or what it is dependent upon. Some considerations in regard to the nature of wear will be advanced further on; but whether wear is a direct function of the tensile strength of steel, or of its elongation, or of its elastic limit, or of its resilience, or any combination of these, or indeed, as seems somewhat probable, of the amount of distortion by bending that a piece of steel will suffer, is a problem yet to be solved. It may be that wear bears a direct ratio to the elongation within the elastic limit, or to the amount of work done within the elastic limit whenever a particle is worn off; or, indeed, wear may be a direct function of the granular structure of steel, the wear being more rapid as the granular structure is coarser, or *vice versa*. Or, finally, wear may be due to a combinations of causes, and each cause may require for its elucidation a different physical test. It is perhaps, therefore, not strange, in view of this want of knowledge, that, in a series of steels arranged according to loss of metal, or on the principle of wear, the physical qualities which we are now able to measure should not show uniform gradations throughout the series. But, it seems to me, this reasoning does not tend to throw doubt on our ability to draw conclusions that will be valuable from the work which we have in hand. For the question we are studying is not what does wear depend upon, but what chemical composition, and what physical properties, are, in general, characteristic of such rails as have in actual service given least loss of metal per million tons' burden? While the answer to this question may not solve the whole problem of wear, yet it cannot fail to throw light on the relation between the chemistry and physics of steel and its wearing power, which, after all, with our present knowledge of steel metallurgy, is all the knowledge we are able to utilize.

(To be continued.)

NOTE ON STEAM CYLINDERS.

By William Dennis Marks,
Whitney Professor of Dynamical Engineering, University of Pennsylvania.

In the majority of steam engines hitherto built but little thought seems to have been given to the relative lengths of the stroke and diameter of the steam cylinder, as affecting the wasteful condensation of the steam used.

The writer has already called attention to the fact that, if the condensation is solely dependent upon the surface exposed to the steam, as compared with the cylinder's volume, that the steam cylinder should have an equal stroke and diameter.*

On the other hand, it should also be borne in mind that the time of exposure of any condensing surface may affect the amount of condensation, and that if we regard the amount of condensation as directly proportional to the time of the exposure of any given area of condensing surface, *the amount of condensation becomes proportional to the product of the surface exposed by its time of exposure.*

Since, however, the interior of a cylinder continually becomes hotter, approaching more nearly to the temperature of the steam the longer it is exposed, we see that the condensation is not directly proportional to the time of exposure of any unit of area, and it seems natural to suppose that the condensation at first contact with the colder sides of the cylinder would deposit a dew, or film of moisture, and that the known slow powers of conduction of iron for heat would prevent much additional condensation in the time usually allotted to one stroke, thus rendering the amount of condensation almost independent of the time of exposure of the condensing surface.

If, however, we do assume that the wasteful condensation is proportional to the time of exposure as well as the area of the surface exposed, it can be shown, by means of the differential calculus, that the stroke of any steam cylinder should equal twice its diameter, in order that the condensation shall be a minimum for any given volume of cylinder.

* The Relative Proportions of the Steam Engine. Lecture 1, Marks. Lippincott & Co. 1879.

Cotterill, in "The Steam Engine," advances the theory that the water of condensation of the steam, while expanding and doing useful work, is carried out in the exhaust, and that none of it remains in the cylinder to interfere with the entering steam at the next stroke, and further, that the water wastefully condensed at the high temperature of the entering steam is re-evaporated, at least in part, if the engine is worked expansively during the latter part of the stroke, when the pressure and temperature are less, heat being given out by the cylinder. Thus we see that if time is assumed to have no effect upon the amount of condensation, we have stroke and diameter equal; if the condensation is proportional to the time, the stroke equals twice the diameter; and further, the condensation is greater as the difference of temperatures of the cylinder walls, and the steam is greater, and the time it is allowed to act is increased, which seems to demand superheating of the steam in order to have enough surplus heat to heat up the cylinder without wasteful condensation, and a diminution of the surface to be heated up with regard to the time of contact. Much speculation has been indulged in on these points, but we have as yet no experiments which will do more than verify theories in the rudest manner.

We are safe in assuming, until we have much more accurate experimental data than at present giving proof to the contrary, that the time proportion of stroke to diameter in steam cylinders lies much nearer one than two.

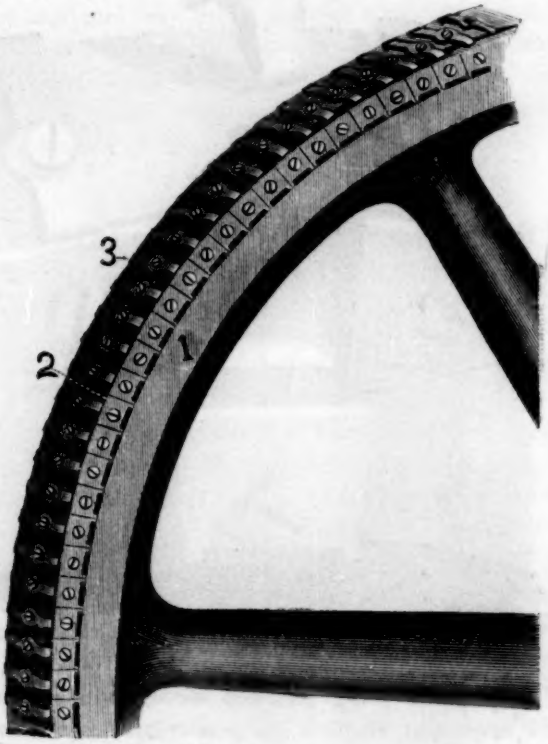
Philadelphia, January, 1881.

Cheap Motors.—A prize of 1000 fr. ($200) has been awarded to M. de Bisschop for a small motor, suited to family use, on the recommendation of M. Tresca, as chairman of the committee. Although it is worked by gas, which is always a dear fuel, this inconvenience is more than compensated by the economy attendant upon the small amount of care that is required. Machines which do a work of 5 kilogrammetres (36·17 foot pounds) per second, use only two cents' worth of gas per hour, at the Paris price; the machine of 25 kilogrammetres (180·8 foot pounds) use five cents' worth. The larger machines are sold for $180, the smaller for $100.—*Bull. de la Soc. d'Encour.* C.

NOVEL MODE OF ORIGINATING AN INDEX WHEEL.

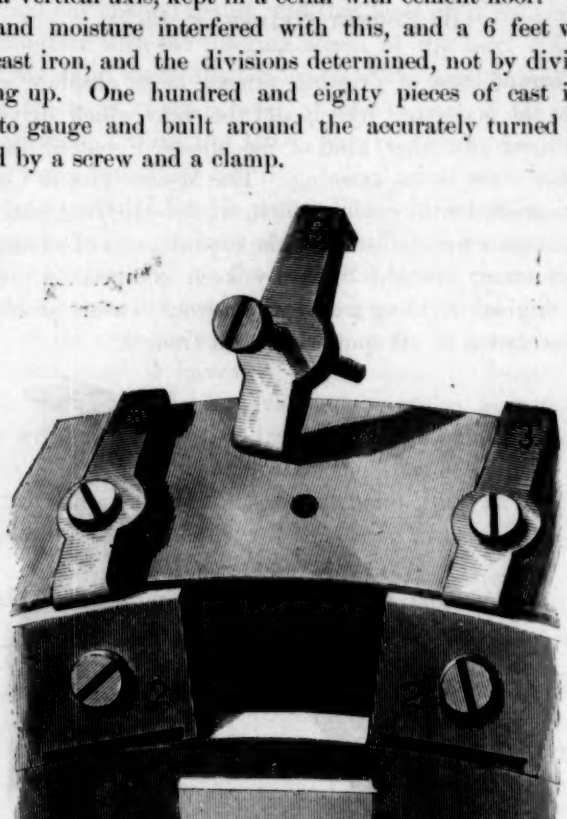
By Robert Grimshaw, Ph.D.

In the manufacture of printing presses more absolute accuracy is required in the main spur wheels and the racks which drive the bed than in almost any other kind of machinery, if indeed, the demands of any other class be so exacting. The Messrs. Hoe & Co., of New York, not satisfied with results which, while satisfying their patrons, might at the same time fall short of the requirements of advanced design and construction, brought forth by keen competition, resolved to obtain an original dividing wheel which would ensure absolute timing in the presentation of all spur wheels cut from it.



One specially made by Whitworth was returned as not equal to what the Hoes had themselves accomplished, and it was resolved to make a new one "for all time."

An attempt was made to graduate a 20 feet wheel, of seasoned wood, on a vertical axis, kept in a cellar with cement floor. But temperature and moisture interfered with this, and a 6 feet wheel was made of cast iron, and the divisions determined, not by dividing, but by building up. One hundred and eighty pieces of cast iron were filed true to gauge and built around the accurately turned rim, each being held by a screw and a clamp.



One of these pieces being removed serves as a stop, to cut one tooth of the main spur wheel of the gear cutter; and then the opposite tooth is cut, and so on, every precaution being taken, as slow cutting, cutting alternately on opposite sides of the rim, to guard against errors from temperature.

The one hundred and eighty pieces were of cast iron, were exactly alike and interchangeable.

Great care was taken in fitting them to keep the metal cool, as it was found that holding one of the pieces, which had been fitted to gauge, in the hand for a few seconds would expand the metal so that it would not reach the bottom of gauge by a sixteenth of an inch; also, that inserting a piece of tissue paper, equal in thickness to the thousandth part of an inch, in the side of gauge would have the same effect. When the pieces were first fitted to the wheel it was found that they lacked three-sixteenth inch of a perfect circle, which made it necessary to reduce very slightly the diameter of the wheel. This was done by revolving the wheel very slowly by hand on a vertical fixed axis, which accurately fitted the hole in wheel, against a stationary cutter, very hard and very sharp, making necessarily more of a scrape than a cut. Then the pieces were again fitted, and it was found all had to be altered, owing to the change in the size of wheel. This operation was repeated many times, and although much time was spent it was deemed advisable in attaining the perfection desired.

THE POLARIZATION OF SOUND AND THE NATURE OF VIBRATIONS IN EXTENDED MEDIA.*

By S. W. Robinson,
Professor of Physics and Mechanics, Ohio State University.

The phenomena of polarization of light, heretofore supposed due to transversal vibrations can be explained on the basis of longitudinal vibrations alone. Polarization of sound, extends the theory of longitudinal vibrations to those in all possible substantial media, including luminous ones.

The object of the following article is to show, by theory and experiment, that longitudinal vibrations, such as in sound waves, can be polarized; and not only this, but also to show that it is irrational and improbable for vibrations in extended media generally to be primarily otherwise than longitudinal. All this is aimed especially at the *transversal theory* of light.

It is well known that light can be radiated, reflected, refracted,

*Copyright 1881, by S. W. Robinson.

diffracted, diffused, can be made to interfere and can be polarized. All these effects are known to be common to sound, except the last, and it is for the sole purpose of explaining this in light that the convenient theory of transversal vibration has been set up by physicists, for the single case of luminous vibration. It is, therefore, only necessary to polarize sound to place all the known effects of luminous waves in common with sound waves, or to make the theory of longitudinal vibrations universal.

Assent to the above notions will be the more readily given after noticing the consideration that, in polarized light it is not necessary to suppose the vibrations transversal till after passing the polarizer, and that the latter imparts an effect equivalent to a lateral impulse, as due to its one-sided action upon the ray transmitted, thus giving cause for vibrations which are more or less transversal; also it is to be noticed that transversal vibrations are not to be assumed impossible when sufficient cause exists; it is simply assumed that the cause is insufficient when a material particle is made to vibrate from the action of a disturbance at a remote centre transmitted to the particle considered the centre, the transmission, and the particle considered being supposed as belonging to a homogeneous medium of indefinite extent. As regards the nature of the vibratory movements of particles of luminiferous ether may we not justly ask that, if we can go through such a range of density as from platinum to hydrogen without a change in the nature of the vibrations, where, as we rise in the scale of ethereal tenuity, shall longitudinal end and transversal begin? Why should the luminiferous ether, now considered as a substance, have a peculiar form of vibration? If ether undulations can be polarized, why not undulations generally? These questions are not answered by the highest authorities. The short of it all seems to be that, if polarized light had never been discovered probably the device of transversal vibrations never would have been set up. Indeed, so eminent an author as M. J. Jamin says in his three volume work on Physics at the outset, in his lesson on polarization, and subsequent to the treatment of interference, diffraction and other phenomena: "What has been said previously of the movement of luminous waves is absolutely independent of the directions of the vibration. * * * We have seen in acoustics that the oscillations of the molecules of air are in the directions of propagation of sound; the same when rods or strings vibrate longitudinally, but are perpendicular to the direction

of propagation in waves on a liquid, or when strings and rods vibrate transversely. In general, imagine in any medium any centre of disturbance whatever; it imparts to any given molecule a vibratory movement, generally oblique to the direction of radiation, and which can be decomposed into two others, one longitudinal and the other transversal. Experiment and calculation prove that these vibrations give rise to two species of concentric waves, which will have unequal velocities of propagation. * * * These considerations apply to the ether as well as to heavy bodies. We ask if these waves coexist in this ether, which produces the light better, the longitudinal or the transversal vibrations? This question can only be answered by experiment, which we now proceed to do."

This is a more complete statement than usually met with on undulations. We find, indeed, a denial of any necessity for transversal vibrations except in polarization, and even there a general question is raised as to the direction of vibration, but evidently with the expectation of deciding it in favor of transversal by experimental polarization. Also, we find support of the doctrine of longitudinal vibrations for media of indefinite extent, and of transversal at the limiting surfaces of media, such as in waves on water. But the general theory of oblique vibrations resolved to components we find beset with doubts and difficulties, especially if we are to admit unequal velocities of propagation, as claimed. For instance, what particular component is the velocity of light to have? Do the varieties in velocity account for the varieties in color? Even this would compass but a part of the components, and what office have the remaining ones? A peculiar obliquity, or component of the same, would necessitate a peculiar condition of the radiant proper for provoking a certain obliquity, etc., in the surrounding ether. If this be granted, what is the character of a vibration at a distance from the radiant? Suppose a radiant exciting oblique vibrations in particles of the ether near it; this movement, transmitted to the next particle, will tend to be in a parallel line, and so on from particle to particle; likewise for another vibration at another point of surface of radiant. This would cause all lines of vibratory motion to have such directions as to pass through the radiant, so that at a remote point all particles would be found vibrating in lines contained within a visual angle of the radiant, with respect to that point. For example, in direct sunlight all lines of vibration of particles at the earth would lie within the angle of the sun, of about

half a degree, and hence almost perfectly longitudinal. Again, as to the motion of a remote particle, it should be the resultant of all actions extended to it from the radiant, and hence longitudinal. In support of this we have the famous principle of Helmholtz regarding the action of natural forces among mutually interacting material points, viz.: that the forces must be central forces and functions of the distance, and hence motions of remote particles can only be longitudinal with reference to the centre of force.

From these considerations transversal vibrations, at a considerable distance from a radiant, seem impossible, hence if light can be polarized why not undulations generally. The writer, after much study, became convinced of the possibility of this about eight years ago. At two different periods apparatus was made for putting the matter to an experimental test, and this was done last May with satisfactory results. I propose now to describe the apparatus and give the results.

The means adopted for polarizing the undulations is the same as that for polarizing light by reflection. It is well known that when sound passes from one medium into another whose velocity of sound differs, the sound is refracted. Recent investigations of Henry, Tyndall and others have indicated that when sound encounters a change of density of medium, as when passing from clear atmosphere into a wall of fog, there is a reflection of sound. Altogether there seems no doubt but sound acts like light in these respects, that is, on meeting a change of refractive power, it is both reflected and refracted, as light is at the surface of water or of glass. The reflected light being polarized, the reflected sound is supposed to be.

Applying the laws of Fresnel and Brewster—1st, that the index of refraction is equal to the ratio of the velocities of the waves in the media; and 2d, that complete polarization is obtained for the particular case of right angled reflected and refracted component rays, we are guided to the proper conditions. We conclude that any two substances having different velocities of propagation of waves may be selected. For instance, two gases, like hydrogen and air, any two liquids, any two solids, a solid and a gas, or, generally, any two media whatever. Considerations of convenience would indicate air and illuminating gas, and these were chosen for the present purpose. The velocities of propagation in air and coal gas being as 1125 and 1420, the index of refraction, according to the first law above, is $n = 1{\cdot}26$.

The second law gives for the polarizing angle of incidence, tanget $i = n = 1{\cdot}26$, or $i = 51\frac{3}{4}°$, the rays or waves being in the gas. To realize this incidence upon a surface of separation between the gas and air, the cool gas was placed in L-shaped tubes, AB, Fig. 1, having a portion cut away at the angle, as shown at CD. The branches of the L

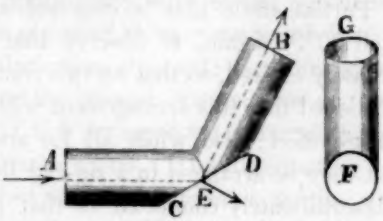


Fig. 1.

make equal angles of $51\frac{3}{4}°$ with the normal to CD. A delicate membrane was gummed to the tube covering the opening at CD, also shown at F, the object of which was to retain the gas and maintain a polarizing surface, CD. The arrow at A indicates a ray which is incident at E, and is then in part refracted outward at E in a direction perpendicular to the reflected component EB. Each tube was about one inch in diameter and three inches long. A number of these were made of tin, each with one end slightly larger than the other, so that they could be joined up, stove-pipe fashion, to any desired extent. Being cylindrical, the plane of one L piece could be placed at any angle with the plane of the preceding one, according to the desired polarizing test.

Fig. 2 shows the manner of joining the tubes, giving the effect of nine polarizing surfaces, like nine plates of glass in light arranged at the polarizing angle. The nine plates of glass can be used in two

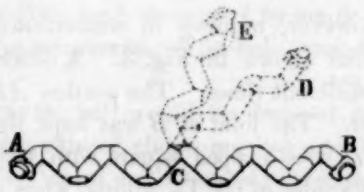


Fig. 2.

parts—one part, 4 for instance, serving as a polarizer and the remaining 5 as analyzer. The ends at A and B were capped with membranes and the whole filled with illuminating gas. Thus AC

may serve as a polarizer and CB, or CE, or CD as analyzer. When arranged as in ACB or ACE all conspire to the same effect of polarization; but when arranged as in ACD, the plane of all the L pieces in CD being at right angles to that of those in AC, the effect of one part antagonizes that due to the other, and to a maximum degree as regards the angle. Partial effects may be obtained with intermediate angles between 0 and 90°. Again, we observe that the L pieces of Fig. 2 may be alternately crossed, so that no two contiguous ones will be parallel. It is believed that this arrangement will give the greatest possible antagonistic effect; also, while all Ls are in one plane it is not necessary that they be arranged in a zig-zag line, like AC and CE, but may be indiscriminately connected in that plane. The few experiments made with the above-named arrangements gave very marked results. Of course it need not be confined to nine or any particular number of the L pieces.

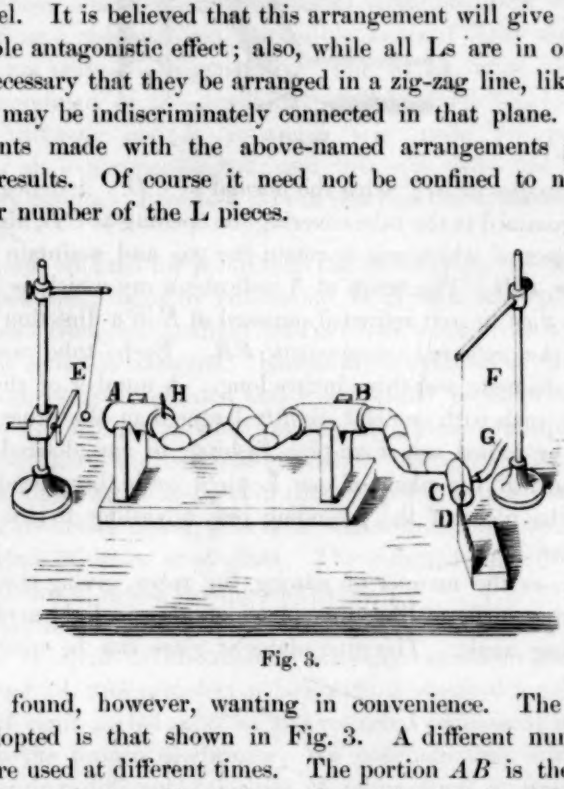


Fig. 3.

It was found, however, wanting in convenience. The apparatus finally adopted is that shown in Fig. 3. A different number of L pieces were used at different times. The portion AB is the polarizer and BC the analyzer. The joint at B was kept tight with beeswax; the ends at A and C were capped square with the same membrane material as were the angles of the Ls, giving, when charged with illuminating gas, a continuous zig-zag column from A to C. The L pieces of the polarizer enter half Ls at A and B, the latter having a common axis and resting in bearings at A and B in the standards, as shown. The object of this is to enable the experimenter to turn the

polarizer readily from cross to parallel, etc. This convenient arrangement of the polarizer is due to my assistant, Mr. Wright. Although applied to the polarizer, it is evidently equally applicable to the analyzer instead. The half L angles were not covered with membranes, but left solid, with gradual inside curvature. Membranes might have been applied here with partial polarizing effect. The half L solid angles are supposed to have detracted in a measure from the percentages of polarization obtained; but this sacrifice is more than compensated for by the greater convenience and constancy of conditions obtained. If this arrangement gives decisive results, of course more perfect apparatus would. The illuminating gas was admitted by a nipple and rubber hose at *C*, the same flowing the length of tubes and issuing in a small jet at *H*; my assistant kept this ignited, and used the flame length as a pressure indicator, and it served admirably.

The first trials were made by blowing an organ pipe in front of the membrane *A*, to agitate the gas column. A small mirror was attached to the membrane *C*, reflecting a pencil of light upon a screen. The deportment of the image indicated complex and inadmissible vibratory movements of gas column, and besides quantitative indication was found preferable to qualitative; thereupon the quantitative impulse and indicator pendulums were adopted, as shown at *E* and *F* respectively, Fig. 3. An ivory ball, $\frac{1}{4}$ inch in diameter, suspended by a thread of 8 inches length, was used at *E*, and so placed that when at rest the ball would just touch the membrane at *A*. The impulse was imparted by bringing the ball back against the stop, shown by means of a spatula held in the hand, and then allowing it to swing free against the membrane, each time with a definite predetermined arc. So much of the impulse as reaches *C* knocks the pendulum *F* through a certain arc, the same being measured on the scale *D*. This pendulum was a small, hollow glass bead, suspended by a silk fibre and trained delicately against the membrane. The bob carried a pointer for the scale *D*.

In the experiments the ball would be dropped against *A* some five or ten times, at intervals of about ten seconds, the corresponding deflections at *D* being noted and recorded; then the polarizer would be turned 90° and like observations noted. Again, 90° would be turned off, etc., etc.; occasionally the length of impulse arc would be changed, or more or less L pieces applied, and in each case a large number of observations made.

In the experiments the initial pulse seemed to be followed by a series of vibrations in rapidly decreasing amplitudes; but it is believed that the initial pulse is equivalent to a genuine sound wave, or an undulation. Evidence of soundness of this view is found in the fact that the velocity of sound can be satisfactorily determined by similar pulses sent through tubes of 25 or 50 feet length. It was evident that the initial pulse only was concerned in the first swing of pointer at *D*.

Results of Experiment.

Polarization of undulations by reflection from a surface separating coal gas and air. Signs = and + indicate relation of polarizer and analyzer, as in one plane or in perpendicular planes respectively.

	Gas in tube.			Air outside		
Series.	=	+	No. obs.	Per ct.	Ls in *AB*.	Ls in *BC*.
1	10·74	10·39	60	3·26	1	2
2	4.11	3·98	40	3·16	1	2
3	9·09	8·62	80	5·17	1	2
4	10·75	9·44	112	12·19	3	3
5	4·30	4·16	73	3·25	3	3

Total number of observations, 365.

Mean polarization, weights by number of observations, per cent. of unpolarized ray, 6·41.

	Air both inside and outside of tube.					
1	11·44	12·21	26	—6·73	1	2
2	8·34	8·40	64	—0·72	3	3

Total number observations, 90.

Polarization, per cent., 2·46.

The per cent. is obtained by dividing the difference of the values under the signs = and + by the value under =.

In obtaining the above results different impulse arcs were used, also different numbers of L pieces, as indicated in last column. The values under = and + are the divisions on scale *D* of swing of indicator pendulum, each being a mean of the number of observations named.

The results show a decided effect of polarization, though of smaller percentage than desirable. If the negative result obtained, with air in and out when it should have been nothing, is to be taken as due to some bias of the apparatus, it would be fair to add a like value to the polarized effect, thus changing the 6·41 to + 8·87.

But as a higher percentage was looked for, the instrument itself was now examined for possible faults; the membranes were all found under considerable tension, whereas, of course, they should be perfectly free from it. After completely slackening, then, as was supposed, the experiments were continued with the following results;

Polarization Continued.

Coal Gas in L tubes and Air outside.

Individual results.

Polarizer having 4 Ls and Analyzer 5 Ls.

=	+	=	+	=	+	=	+	=
6·0	6·0	8·0	5·0	6·5	5·8	6·2	6·0	6·0
6·0	6·0	7·5	5·5	6·5	5·5	6·0	5·2	6·2
6·2	6·0	7·0	5·3	6·3	5·6	6·5	5·2	7·0
6·1	5·8	7·5	5·2	6·5	5·2	6·4	5·1	6·2
6·0	5·7	7·0	5·0	6·2	5·7	6·3	5·5	6·1
6·1	5·5	7·2	5·2	6·6	6·0	6·3	5·1	6·1
6·2	5·8	6·5	5·0	6·8	5·2	6·2	5·2	6·1
6·0		7·0	4·9	6·2	5·2	6·5	5·4	6·5
		7·0	4·0	6·3	5·3	6·3	5·8	6·8
						6·3	5·2	6·4
Means 6·07	5·83	7·19	5·01	6·43	5·50	6·30	5·37	6·34

In this series each value given in any column is the number of divisions on the scale *D*, Fig. 3, of the deflection of the indicator pendulum bob. After obtaining one column of results the polarizer, *AB*, was turned 90°, and the next column obtained. Thus the several columns were obtained.

On completing this series of observations air was passed into the L tubes, completely displacing the coal gas, so that the membranes were now suspended in mid air. Other conditions remained the same. The indicator pendulum now responded to the same impulses so slightly as to be barely observable, but not measurable, and they were apparently the same for the polarizer in all positions; that is to say, when air was upon both sides of the reflecting surfaces there was almost no appreciable reflection. This evidently should be the case, as the light membrane itself is now the chief cause of reflection. This, compared with the results obtained with gas in the tubes, shows that a considerable reflection is due to surfaces of separation of gases differing in density.

As regards the polarization, we observe that every mean under "=" is larger than any mean under "+", a fact which cannot be assumed accidental, nor explained on any other ground than polarization. To find the percentage of this in a single result, we have

Means of the above series.

=	+
6·07	5·83
7·19	5·01
6·43	5·50
6·30	5·37
6·34	
Means, 6·47	5·43

$$\text{Per cent.} = \frac{6{\cdot}47 - 5{\cdot}43}{6{\cdot}47} = 16{\cdot}1.$$

Whole number of observations, 80.

At this point the membranes were again examined and found to have appreciable tension, though supposed to have been entirely slackened at the beginning of the series of observations just cited. It was thereupon determined to slacken them with the utmost possible care, and continue the observations. The following table of individual results was then obtained in the manner explained above:

POLARIZATION CONTINUED.

Coal Gas in tubes and Air outside of tubes.

Polarizer having 4 Ls and Analyzer 5 Ls.

Individual results.

=	+	=	+	=	+	=	+	=	+	=	+	=	+
1·2	0·9	2·0	1·0	1·5	1·0	1·6	1·0	1·8	1·4	1·5	0·9	2·0	1·0
1·5	1·0	2·1	1·2	1·5	1·0	1·4	1·1	1·5	1·2	1·5	1·0	2·1	1·2
1·5	1·0	1·8	1·1	1·8	1·0	1·8	1·1	1·5	1·4	1·5	1·0	1·8	1·1
1·5	1·0	2·0	1·0	1·3	1·0	1·9	1·2	1·7	1·2	1·5	1·0	2·0	1·0
1·5	1·1	2·0	1·0	1·3	1·0	1·9	1.0	1·7	1·1	1·5	1·1	2·0	1·0
	1·0	2·0	0·9	1·2	1·0	1·8	1·0	1·7	1·2	1·5	1·0	2·0	0·9
		2·1	0·9	1·3	1·0	1·6	1·0	1·8	1·0			2·1	0·9
				1·5	1·0		1·1	1·7	1·0				
							1·1	1·7					
							1·1	1·6					
Means,	1·44	1·00	2·00	1·01	1·45	1·00	1·71	1·07	1·67	1·19	1·50	1·00	2·00	1·01

For gas displaced by air; other conditions the same; deflection, 0·00; polarizer turned 90° immediately following each column of results.

The smallness of these results, compared with those of the previous series, may be explained on the ground of extreme and entire slackness of the membranes; also the slackness is still further evinced by the fact that, when air displaced the gas no deflection of the indicator pendulum was observable in response to the impulses. Tense membranes would have turned the sound waves somewhat, and in the manner of the rebound of a drumstick.

To obtain the percentage of polarizing effect, we have:

Mean of the above series.

=	+
1·44	1·00
2·00	1·01
1·45	1·00
1·71	1·07
1·67	1·19
1·50	1·00
2·00	1·01
Means, 1·68	1·04

$$\text{Per cent. } \frac{1{\cdot}68 - 1{\cdot}04}{1{\cdot}68} = 38{\cdot}1.$$

These results establish the following facts for sound waves or for undulations, viz.:

1st. A decided reflection occurs at a surface separating two gases of different density, confirming the views of Henry and Tyndall in this regard.

2d. In repeated reflection from such surfaces the intensity of the final component varies with the relative positions of those surfaces, the same following the laws of polarization in light, from which we conclude that longitudinal undulations can be polarized.

With sound polarized, we complete the list of effects for longitudinal undulations which are known to light, viz.: radiation, shadows, reflection, refraction, diffusion, diffraction, interference and polarization; and the laws are common for like conditions, viz.: for intensity of radiation in ambient space, $\frac{I}{d^2}$; in parallel space, $\frac{I}{d^1}$; in prismatic space, like a tube, $\frac{I}{d^0}$; for shadows, reflection, refraction and interference as well known; for diffusion, as when a steam whistle is sounded,

filling the air with its ring; for diffraction, as sound waves diverging rapidly after passing a narrow space between buildings, like light in passing a narrow slit and diverging; and, finally, for polarization, as above. In studying these comparisons we should recollect the vast difference between the properties of undulations in heavy and ethereal media. Thus the wave length is very great and the velocity of propagation very small in sound as compared with light. This seems sufficient to account for the greater definition of shadows in light; but when a slit is made as narrow for light as for sound, in comparison to wave length, the diffraction divergence is probably about alike; that is, the shadow of a silk fibre in light is much like a sound shadow of Bunker Hill monument, for instance. With these considerations it may be reasonable to expect incomplete or only partial polarization with such apparatus as employed above.

The conclusions to which we are conducted by the foregoing may be summed up as follows:

1st. That vibrations in extended media, produced from the action of a remote single centre of disturbance, can only be longitudinal, even in light.

2d. That vibrations will be to some extent transversal when due to two or more centres of disturbance not in the same line, as when two or more independent co-existent systems of undulations combine into one, or when a simple system is modified by such lateral disturbance as a reflection or a refraction.

3d. That undulations, to be in a condition called polarized, must consist of vibrations which are transversal, and that no necessity exists for assuming vibrations transversal in front of a polarizer.

[NOTE.—As regards longitudinal, oblique, transversal, etc., in the foregoing, the estimate is to be taken by comparing the direction of the line of vibration of a particle with that of propagation of the wave.

My acknowledgements are due to Mr. Clarence H. Wright, who, while a student in my physical laboratory last spring, rendered valuable aid in the experimental work. The arrangement of the polarizer as regards the *half* Ls, *A* and *B*, Fig. 2, and the bearings, whereby convenience is secured, is due to him.]

DESCRIPTION OF A MODEL OF THE GYROSCOPE FOR CLASS ILLUSTRATION.

By B. HOWARD RAND, M.D.

The gyroscope is usually spoken of as a toy. It is not such. It is as important an illustration of the law of centrifugal force as the Atwood machine is of that of gravitation.

It is seldom described in those gatherings of blunders known as "text-books;" and so much the better for the poor children who have to commit the statements (true or false) to memory. It is still more rarely shown to a class, perhaps because the "professor" does not understand it himself.

One great difficulty for the beginner in the study of mechanics is the erroneous definition of *inertia;* another, the misleading use of the words "tendency" and "tend," as applied to particles under the influence of force.

Inertia in the dictionaries and encyclopædias is used as synonymous with *vis inertiæ.* In the text-books it is described as a *property* of matter by which when at rest it "tends" to remain at rest, and when in motion to continue in motion in its original direction. That dead matter can exert force, as the term *vis inertiæ* requires, is absurd; that matter can "tend," is equally so. The mistake has continued from the fact that the compilers of text-books have copied the errors of their predecessors, and the teacher too often follows the book without independent thought.

Inertia is not a force, neither is it a property of matter. It is a convenient word to represent the fact that all change in matter, whether physical or chemical, is due to force. Matter, as we see it, is composed of many particles, hence the communication of the force requires time, in order to affect each particle in succession. Force is never lost, and a body influenced by it will remain under its influence until the force is neutralized or altered by other forces, either active or so-called passive. Among the latter are classed friction and resistance of the air by which the original force is converted into a new form, usually heat.

Perhaps the best illustration of the fact that the "inertia" of a body at rest is due to the law that the communication of motion to a mass requires time, is to be found in the starting of a long train of coal cars. The driver backs his engine until the "bumpers" touch

and the coupling links are slackened; then, starting the engine, it picks up one car after another, and thus puts the train in motion. Were the train "screwed" together, the adhesion of the driving-wheels would fail to give purchase enough to start it.

The "inertia of the plane of rotation," as seen in a boy's hoop or top, means simply that the original muscular force applied has to be exhausted before that of gravity can show its power.

The gyroscope is so well known that a description of it might seem needless. It may be worth the little time necessary to describe it to those who wish to follow the ideas of the model closely.

It is a smooth, heavy disc of metal on a shaft, which is suspended in a ring by two points at its ends, so as to permit of free rotation, Fig. 1. It is started by quickly drawing off a string, previously wound around the shaft after the fashion of a boy's top. The ring is firmly fastened to a rod, which has at its middle a cup, and on the other side of the cup a counterpoise weight, which can be fixed by a set screw so as to balance, underbalance or overbalance the disc. The cup rests on the point of an upright stem fastened in a base board; thus, hung like the ordinary magnetic needle, the whole is free to move in both a horizontal and a vertical plane.

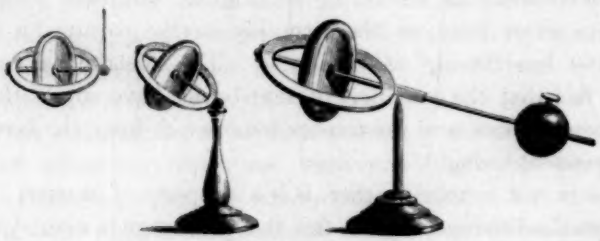


Fig. 1.

When the disc is balanced and the string pulled no movement, other than its own on its axis, is noticed. For convenience, it may be supposed to have right-handed rotation, to wit, that of the hands of a watch.

When the disc is not in rotation, if underbalanced it falls to the base-board or table, if overbalanced it is caused by the weight of the counterpoise to rise. Although these movements are not strictly in a vertical plane, they may, for the purpose of making the explanation shorter, be so considered.

When the disc, after being set whirling, is underbalanced, instead of falling it remains in the vertical plane, and at the same time a motion,

called "precessional," of the whole system around the upright stem is noticed. This precessional motion is more rapid as the velocity of the disc is greater. It is in an horizontal plane, and its direction is right-handed. Being in a plane at right angles to that of the disc, the motion is in a direction opposite to that of the upper edge of the disc. As the disc gradually, from friction of the bearings and of the air, comes to rest, the precessional motion diminishes, slowly ceases, and the disc falls. When overbalanced these movements are reversed.

The model which I submit is intended to explain these phenomena. It presupposes a knowledge of the principle of the composition and resolution of force. It can be made by any one of thick pasteboard, or at a small expense by a tinsmith.

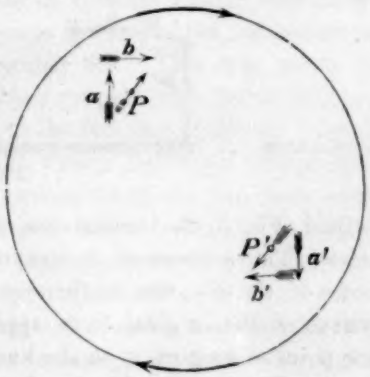


Fig. 2.

a a' vertical components. *b b'* horizontal components. *P P'* Particles under influence of the centrifugal force.

On the opposite sides of the disc, which is mounted on a stem with a counterpoise, are cut slots in the form of arrows, as represented in the cut, Fig. 2. In these slots are placed arrows, slightly smaller than the slots. These are hung by wire near the barb, so that they move freely through the slots. The arrow (a) on the left-hand side is weighted by solder at its butt, that on the right-hand side (a') is weighted at its point. When the disc is tilted the arrows will still remain vertical, but with the points in opposite directions. The arrangement of the horizontal arrows will be explained later. The supposed particles, p and p', indicated by dots painted on the disc, are under the influence of two forces; first, that of the arm used in drawing off the string. This impels them in the direction given

when the disc was in a vertical plane. Second, that of gravity, which pulls the disc towards the earth.

We have represented by the arrows the components, a and b, and a' and b' of the resultant motion of the two supposed particles, one near the upper edge of the disc, the other near the lower edge, and on opposite sides; they are moving in opposite directions at the same time. The direction of the rotation is shown by arrows painted on the disc near its upper and lower edges.

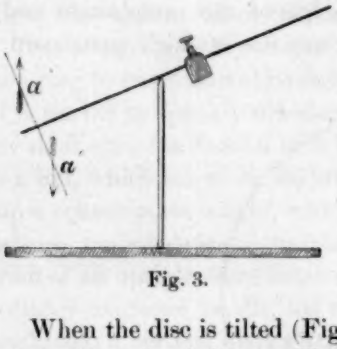


Fig. 3.

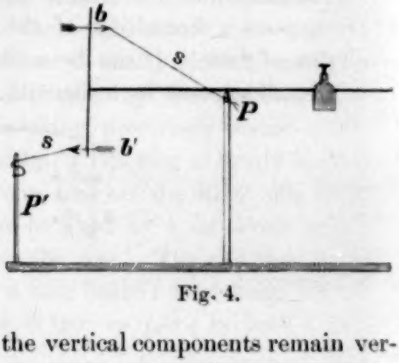


Fig. 4.

When the disc is tilted (Fig. 3) the vertical components remain vertical, like plumb-lines. The pressure of a upwards and a' downwards on opposite sides of the disc, due to their continuing in their first direction by virtue of the original force applied, will cause a movement around the point of support, s, on the known principle of a "couple," or bent lever. This can readily be shown by pressing at the same time on the front and back of the disc at the points indicated by the barbs of the arrows, the disc being counterpoised. The precessional motion will result.

The arrows representing the horizontal components are hung to the disc by a wire hinge near the point. They are attached by strings, s, to posts on the base-board, P and P', one in front of the disc, the other behind it. The holes for the strings are in the barbs of the arrows. The heads of the arrows indicate the pressure of the original force in opposition to an attempt to change the direction of the original vertical plane of rotation by the precessional movement. This can be shown by pressing near the upper and lower edges of the disc, as the arrows point, when the disc will be forced upward by a vertical force acting as a couple, or through a bent lever, as before,

Fig. 4. The neutralization of the force of gravitation acting on the disc is thus shown.

This explanation of the phenomena of the gyroscope is not claimed as original. The plan of the model for class illustration is believed to be so. The model is on deposit at the Franklin Institute, and any one is at liberty to make a copy.

SOUND FROM RADIANT ENERGY.

The announcement that Mr. W. H. Preece, the President of the Society of Telegraph Engineers, would lecture on the "Photophone and the Conversion of Radiant Energy into Sound," attracted a large number of auditors to the hall of the Institution of Civil Engineers on Wednesday, December 8th. This was partly due to the intrinsic interest of the subject coupled with the well-known ability of the lecturer, and partly to the fact that Professor Bell himself was expected to be present. Mr. Preece began his discourse by a reference to the other three great inventions of the last four years: the telephone, the phonograph, and the microphone, all of which, together with the latest marvel, the photophone itself, were concerned in the transmission and reproduction of sound.

After explaining that sound was a sensation caused by a vibratory motion in the air communicating itself to the drum of the ear, he illustrated the composite nature of light by throwing a splendid spectrum on the screen with the help of Mr. Ladd. Light, he observed, is a sensation of the eye set up by the action of a vibratory motion in the luminiferous ether. The telephone owes its action to an electric current varying in sympathy with the vibrations of the air constituting sound, and it is clear that if a substance could be got which, under the influence of light, would vary an electric current passing through a telephone, the transmission of sound to a distance by means of a vibratory beam would be rendered feasible. Such a substance is selenium, a body discovered in the year 1817 by Berzelius, when he was looking for tellurium, but it is so intractable in its physical properties that Professor Bell has had to overcome a great many practical difficulties in adapting it to his purpose.

We have so recently described the genesis of the photophone and its actual construction that it will be unnecessary for us to follow Mr.

Preece at length. We shall rather aim at presenting the most novel parts of his lecture and the fresh ideas it evoked in the discussion. The history of selenium is in a physical sense very interesting. It is an instance of a little known and somewhat ambiguous mineral, neither metal nor non-metal, which by virtue of a peculiar property, accidentally discovered by Mr. Willoughby Smith, has been chosen from among its fellows and exalted into honor. While seeking for a convenient form of high resistance to be used in cable testing, Mr. Willoughby Smith found that the exposure of a piece of selenium to light generated an electric effect in it which could either be attributed to a diminution of its electrical resistance, or to the creation of a current in the material. This original experiment was exhibited to the meeting by Mr. Willoughby Smith with the aid of a box which could admit or exclude the light from a piece of crystalline selenium connected in circuit with a battery and a reflecting galvanometer. The light of a lucifer match falling on the selenium was sufficient to deflect the light spot off the scale.

Mr. Willoughby Smith's discovery gave rise to the question whether the effect was due to the light, heat, or active rays of the spectrum, and whether it was a diminution of resistance or a new current excited. With regard to the first question, all subsequent investigators have shown it to be due to the light rays, Professor W. Grylls Adams and Professor Bell attributing it chiefly to the yellowish-green or middle rays of the spectrum, and Lieutenant Sale to the red rays. With regard to the second question Professor Adams has distinctly proved that a current is really set up in the selenium by the action of light, without a battery at all being in the circuit—a discovery confirmed by Mr. W. Crookes. The last mentioned investigator coated the vanes of a radiometer on one side with chromic oxide, and on the other with selenium, and found that in May of one year they rotated in a certain direction under the influence of light, while in October of the same year their rotation was in the opposite direction. In searching for the cause of this peculiar behavior he traced it to the use of a sperm candle giving a white flame and making the selenium surfaces to retreat on the one occasion, and the use of a wax candle giving a yellow flame making the chromic oxide surfaces to retreat on the other occasion. Here, then, we have two substances differently affected by rays of unequal refrangibility, the selenium being more sensitive to rays of higher refrangibility or smaller wave length. Mr. Robert Sabine's

experiments with selenium have established the fact that by the action of light on that substance an electromotive force is set up at the surface on which it falls; and Professor Minchin, of Cooper's Hill College, has demonstrated that light falling on one of two tin-foil plates immersed in hard water generates a comprratively powerful current. These observations tended to show that the effect of light on selenium was to generate an electric current; but other experiments by Mr. Sabine and others had proved that there was also a diminution resistance; and, as Professor Adams remarked in the discussion, both effects are produced together, the diminution of resistance being the stronger effect, and it is that upon which the theory of the photophone is based.

The intractable nature of crystalline selenium, and its extremely variable resistance, were first discovered by Dr. Werner Siemens, who found the variation of its resistence under the influence of light to be proportional to the square root of the illuminating power of the light; but when he attempted to construct a photometer on this principle he was met with disappointment owing to the uncertain resistance of the material. Two fragments of selenium from the same piece, prepared in precisely the same way, gave widely different results, and the same fragment altered from day to day. Professor Adams has observed that the resistance decreases by time, and instanced a piece which fell from 7,600,000 ohms in May, 1876, to 7·45 ohms in May, 1877. This liability to secular variation was one of Professor Bell's difficulties in working out the photophone; so, also, was the physical "fatigue" experienced by the mineral under the prolonged action of the light. This was early observed by Dr. C. W. Siemens, in experimenting with his "selenium eye," a simple apparatus consisting of a hollow ball containing a sensitive plate of selenium fixed in the focus of a lens in front of which are two movable shutters, these various parts corresponding respectively to the retina, the crystalline lens, and the eyelids of the human eye. The selenium plate is placed in circuit with a battery and galvanometer, and every time that light is admitted to the selenium by the opening of the eyelids, a corresponding deflection takes place in the galvanometer; the needle returning to its zero position when the light is again cut off. When the action is repeated often the selenium fails to respond as promptly as before, and the effect is lessened. This drawback had also to be overcome by Professor Bell. Various forms of selenium cell employed by him were illustrated by Mr. Preece.

The experiments which have led Professor Bell and Mr. Sumner Tainter to announce the discovery that all bodies are rendered sonorous under the influence of an intermittent or vibratory beam of light were very lucidly described by Professor Bell himself in opening the discussion. He explained how an intermittent beam of light, either luminous or deprived of its luminous rays by passage through a screen of ebonite, and allowed to fall on *thin* disks of any material, wood, paper, metal, gutta percha, glass, etc., caused the disks to give out a musical tone of a pitch depending on the number of intermissions per second, and of a *timbre* depending on the nature of the disk. Even tobacco smoke and crystals of sulphate of copper held in a test tube in the path of the intermittent beam emitted a corresponding tone, and even when the beam was simply focused within the outer ear itself, without any auxiliary appliances whatever, a note was likewise audible. In the short discussion which followed the lecture this conclusion of Professor Bell that all bodies are rendered sonorous by the fall of light in this manner, was pleasantly questioned by Dr. Tyndall, who thought it might be due to the expansion caused by the impact of heat rays; and in support of his remarks he cited an experiment which he had made in the presence of Professor Bell at the laboratory of the Royal Institution. He took the vapors of two volatile bodies, bisulphide of carbon and sulphurous ether, and exposed them successively in a glass vessel to the intermittent beam of light; and he argued that if the effect was due to the absorption of heat and the consequent expansion of the vapor, an audible effect would be obtained from the sulphurous ether, while on the contrary, the bisulphide of carbon would give no effect owing to the fact that it is almost completely transparent to heat. The result was that the sulphurous ether yielded a distinct musical note, and the bisulphide of carbon was quite silent. So far, then, as this experiment goes, Professar Tyndall's surmise is correct; but the subject will have to be cross-examined by a variety of careful experiments ere the question can be set at rest.—*Engineering.*

Progress of Electric Lighting.—We have already referred to the extensive sales of the Brush machine in England and America. A similar demand exists for other machines, and it is said that Siemens Bros. have more than 1000 of their machines now in use for purposes of illumination.—*La Gaceta Industrial.* C.

THE LATEST METHODS FOR PRODUCING PHOTO-TRACINGS IN BLACK AND COLOR.

Two new processes for taking photo-tracings in black and color have recently been published—"Nigrography" and "Anthrakotype"—both of which represent a real advance in photographic art. By these two processes we are enabled for the first time to accomplish the rapid production of positive copies in black of plans and other line drawings. Each of these new methods has its own sphere of action; both, therefore, should deserve equally descriptive notices.

For large plans, drawn with lines of even breadth, and showing no gradated lines, or such as shade into gray, the process styled "nigrography," invented by Itterheim, of Vienna, and patented both in Germany and Austria, will be found best adapted. The base of this process is a solution of gum, with which large sheets of paper can be more readily coated than with one of gelatine; it is, therefore, very suitable for the preparation of tracings of the largest size. The paper used must be the best drawing-paper, thoroughly sized, and on this the solution, consisting of 25 parts of gum arabic dissolved in 100 parts of water, to which are added 7 parts of potassium bichromate and 1 part of alcohol, is spread with a broad, flat brush. It is then dried, and if placed in a cool, dark place will keep good for a long time. When used, it is placed under the plan to be reproduced, and exposed to diffused light for from five to ten minutes—that is to say, to about 14° of Vogel's photometer; it is then removed and placed for twenty minutes in cold water, in order to wash out all the chromated gum which has not been affected by light. By pressing between two sheets of blotting-paper the water is then got rid of, and if the exposure has been correctly judged the drawing will appear as dull lines on a shiny ground. After the paper has been completely dried it is ready for the black color. This consists of 5 parts of shellac, 100 parts of alcohol, and 15 parts of finely-powdered vine-black. A sponge is used to distribute the color over the paper, and the latter is then laid in a 2 to 3 per cent. bath of sulphuric acid, where it must remain until the black color can be easily removed by means of a stiff brush. All the lines of the drawing will then appear in black on a white ground. These nigrographic tracings are very fine, but they

only appear in complete perfection when the lines of the original drawing are perfectly opaque. Half-tone lines, or the marks of a red pencil on the original, are not reproduced in the nigrographic copy.

"Anthrakotype" is a kind of dusting-on process. It was invented by Dr. Sobacchi, in the year 1879, and has been lately more fully described by Captain Pizzighelli. This process—called also "Photanthratography"—is founded on the property of chromated gelatine which has not been acted on by light to swell up in lukewarm water, and to become tacky, so that in this condition it can retain powdered color which had been dusted on it. Wherever, however, the chromated gelatine has been acted on by light, the surface becomes horny, undergoes no change in warm water and loses all sign of tackiness. In this process absolute opacity in the lines of the original drawing is by no means necessary, for it reproduces gray, half-tone lines just as well as it does black ones. Pencil drawings can also be copied, and in this lies one great advantage of the process over other photo-tracing methods, for, to a certain extent, even half-tones can be produced.

For the paper for anthrakotype an ordinary strong, well-sized paper must be selected. This must be coated with a gelatine solution (gelatine 1, water 30 parts), either by floating the paper on the solution, or by flowing the solution over the paper. In the latter case the paper is softened by soaking in water, is then pressed on to a glass plate placed in a horizontal position, the edges are turned up, and the gelatine solution is poured into the trough thus formed. To sensitize the paper, it is dipped for a couple of minutes in a solution of potassium bichromate (1 in 25), then taken out and dried in the dark.

The paper is now placed beneath the drawing in a copying-frame, and exposed for several minutes to the light; it is afterwards laid in cold water in order to remove all excess of chromate. A copy of the original drawing now exists in relief on the swollen gelatine, and, in order to make this relief sticky, the paper is next dipped for a short time in water, at a temperature of about 28° or 30°C. It is then laid on a smooth glass plate, superficially dried by means of blotting-paper, and lamp-black or soot evenly dusted on over the whole surface by means of a fine sieve. Although lamp-black is so inexpensive and so easily obtained, as material it answers the present purpose better than any other black coloring substance. If now the color be evenly distributed with a broad brush, the whole surface of the paper will appear to be thouroughly black. In order to fix the color on the tacky parts

of the gelatine, the paper must next be dried by artificial heat—say, by placing it near a stove—and this has the advantage of still further increasing the stickiness of the gelatine in the parts which have not been acted upon by light, so that the coloring matter adheres even more firmly to the gelatine. When the paper is thoroughly dry, place it in water, and let it be played on by a strong jet; this removes all the color from the parts which have been exposed to the light, and so develops the picture. By a little gentle friction with a wet sponge, the development will be materially promoted.

A highly interesting peculiarity of this anthrakotype process is the fact that a copy, though it may have been incorrectly exposed, can still be saved. For instance, if the image does not seem to be vigorous enough, it can be intensified in the simplest way: it is only necessary to soak the paper afresh, then dust on more color, etc.; in short, repeat the developing process as above described. In difficult cases the dusting-on may be repeated five or six times, till at last the desired intensity is obtained.

By this process, therefore, we get a positive copy of a positive original in black lines on a white ground. Of course, any other coloring material in a state of powder may be used instead of soot, and then a colored drawing on a white ground is obtained. Very pretty variations of the process may be made by using gold or silver paper, and dusting-on with different colors; or a picture may be taken in gold bronze powder on a white ground. In this way colored drawings may be taken on a gold or a silver ground, and very bright photo-tracings will be the result. Some examples of this kind, that have been sent us from Vienna, are exceedingly beautiful.

Summing up the respective advantages of the two processes we have above described, we may say that "nigrography" is best adapted for copying drawings of a large size; the copies can, with difficulty, be distinguished from good autograph, and they do not possess the bad quality of gelatine papers—the tendency to roll up and crack. Drawings, however, which have shadow or gradated lines cannot be well produced by this process; in such cases it is better to adopt "anthrakotype," with which good results will be obtained.—*Photographic News.*

Pictet's Ice Machines.—Pictet has read a paper before the French Society of Civil Engineers upon heat and the general theory of frigorific engines, in which he lays down several important laws and formulæ, and explains some details of the operation in various popular machines. In closing his communication, he invited the members to visit his works, where two ice-making machines are operating with sulphurous acid, one of which produces 1100 kilogrammes (2425 lbs.) of ice per hour.—*Ann. du Gen. Civ.* C.

Laws of Electro-Magnetic Machines.—J. Joubert finds that for a given intensity of field, under whatever other conditions the machine may operate, at the moment when it gives the maximum work the intensity is constant and equal to the quotient by $\sqrt{2}$ of the absolute maximum intensity; the electro-magnetic work is proportional to the velocity; the velocity is in a constant ratio to the resistance. The machines, therefore, differ from ordinary batteries, inasmuch as the battery maximum requires no external resistance—*Comptes Rendus.* C.

Deadening Vibrations.—An encouragement of 500 fr. ($100) has been awarded to M. Anthoni, of Levallois Perekt, for a plan for deadening the shocks and vibrations which result from the use of mechanical hammers, pile drivers, etc. It consists in the interposition of plates and washers of caoutchouc between the base of the machines and their foundations, so as to leave no contact between the metal and the ground, except through the intervention of elastic media. Some of his machines have been put in operation with encouraging results. —*Bull. de la Soc. d'Encour.* C.

Vines from Soudan.—Th. Lécard has found numerous botanical surprises in the immense and dangerous solitudes of Soudan. Among the most valuable novelties are a variety of wild vines, with fruit of a delicious flavor, herbaceous stalks, and perennial tuberculous roots. The beauty and abundance of the fruit, the vigor of the plant, and the ease of culture by simple plantation of the tubercles, lead him to hope that they may be acclimated in France, as a substitute for the vines which are destroyed by the phylloxera. He has procured a large quantity of seeds for distribution to the agricultural and scientific establishments of Algiers, France and other parts of Europe.—*Comptes Rendus.* C.

Dangers of Unequal Loads.—In a recent discussion before an architectural society, in Paris, one of the engineers attributed the fall of the roof of St. Martin market to the unequal distribution of the snow, which had been swept by the wind and drifted in some places to a depth that had never been anticipated. It can readily be seen that such drifts might break a weak purlin, and thus withdraw a part of the support of one of the beams, so as to lead to the destruction of the entire roof.—*Chron. Industr.* C.

Vibratory Forms of Circular Pellicles.—C. Decharme reports some experiments upon circular pellicles of soapy water, which are set in vibration by means of musical rods. He finds that for any given diameter of pelicle the number of nodes are inversely proportional to the corresponding lengths of the vibrating rods. This fundamental relation is the same as the one which he had previously discovered in the vibrations of bubbles, and all his equations appear to be applicable in both cases.—*Comptes Rendus.* C.

Mechanical Action of Light.—Charles Cros refers to a memoir which he addressed to the French Academy on the 20th of May, 1872, in which he anticipated, from the *action* of different media upon luminous rays, a *reaction* of light upon the medium. He proposed certain experiments for rapidly and regularly interrupting the passage of a ray, so as to produce audible sounds, as Graham Bell has recently done by means of the photophone.—*Comptes Rendus.*

[The control of æthereal vibrations by mechanical action appears to have been first demonstrated by Chase, in his experiments before the American Philosophical Society in 1864.] C.

Trouvé's Motor.—For several months M. Trouvé has made numerous experiments with his new motor, which he has attached to the hunting yawl *le Telephone*. The game, not being startled by the noise and movement of oars, allow the boat to approach them very nearly, so as to be captured in large numbers. At first the yawl had a velocity of 1·2 metres per second (2·68 miles per hour). After certain changes a velocity was obtained of 2 metres per second (4·47 miles per hour) when moving against the current, and of 2·5 metres (5·49 miles) when moving with the current. Much greater velocities are anticipated from the more powerful motors which are soon to be built.—*Chron. Industr.* C.

Wool Sorting.—Levoiturier, an entomologist of Elbeuf, has prepared a long list of the coleoptera which he has found in the wools of different regions of the globe, and which he has classified so as to show those which are peculiar to special regions. This classification has rendered an important service to the wool industry, since a simple inspection will often enable the sorter to decide upon the origin, and consequent value, of samples which might otherwise be in doubt.—*Les Mondes.* C.

The Telephone in China.—The Chinese alphabet is so peculiar that there is great difficulty in devising any practicable system for conveying telegraphic messages. The telephone, therefore, is received with peculiar favor by the Chinese government, which has at length decided to establish a complete system of telephones throughout the country, commencing north of Yang Tse Kiang. The work will be conducted under the charge of J. A. Betts, the American telegraphist, under whose superintendence the telegraphic line was built from Tientsin to Taku.—*L'Ingen. Univ.* C.

Application of the Photophone to Solar Explosions.—Abbé Moigno suggests the possibility that the photophone may become a means of intercourse between individuals upon different planets, or even in different systems. Graham Bell, having been invited by Janssen to the observatory of Meudon, examined with great care the photographs of the sun's surface. Janssen having stated that they gave evidence of movements of a prodigious rapidity in the photospheric materials, Bell conceived the idea of employing the photophone for the reproduction of the sound which must necessarily arise from the explosions.—*Les Mondes; Comptes Rendus.* C.

The Odors of Paris.—H. Sainte Claire Deville has analyzed samples of the dark soil which immediately underlies the pavements of Paris, and finds that the odors which arise from it are in no wise injurious, on account of the empyreumatic and antiseptic products which are constantly introduced by the illuminating gas that escapes from the street mains. This is not the case, however, with the sewage material, from which disagreeable odors are constantly exhaled in many parts of the city and its environs. He anticipates from Pasteur's investigations some early discoveries which will relieve them from their cholera producing and typhoid tendencies.—*Comptes Rendus.* C.

Book Notices.

A History of the Jetties at the Mouth of the Mississippi River (Jas. B. Eads, Chief Engineer). By L. C. Corthell, C.E. Chief assistant and resident Engineer during their construction. 8vo. New York: John Wiley & Sons, 1880.

History is composed of battles, and this history portrays *some* antagonisms and exults in *some* victories, whose memories could have been left without an epitaph, with not a little propriety. As a narrative of engineering accomplishment, and an example of controlling a river upon a large scale, the history of the progress, day by day, of the work in overcoming original obstacles, in meeting developed ones, and finally in attaining success, the book becomes an interesting addition to engineering literature.

The great value of the work rests upon its being a full account, with maps and charts, of the Mississippi river. A discussion of the application of the system of controlling currents of rivers by jetties is also given, with a statement of examples in other lands, and a tolerably complete description of the appliances for effecting the work: dredgers, pile drivers, apparatus for preparing concrete blocks, etc., as well as the material of jetty building, mattresses, cribs and cement blocks and their manipulation. In these regards, this work of Mr. Corthell becomes a piece of the standard literature of modern engineering, and demands a place in every library of the class. R. B.

Searles' Field Engineering. A hand-book of the Theory and Practice of Railway Surveying, Location and Construction. William H. Searles, C.E. 12mo. New York: Wiley & Sons, 1880.

At once the most profitable and the most useful technical literature, is that which has adapted science to common use; and the text-book, or hand-book, which bridges over the chasm between the learning of the schools and the applications to practice, affording either knowledge or aiding memory, supplies an essential and constant want. Such books are necessarily incomplete in elementary information, incomplete in logical deduction, incomplete in universal application; but in all these regards of information, deduction or application they need not be erro-

neous. In fact, their end is best served when they are comprehensible, correct in statement, and suited to meet *usual* demands in the particular technical field to which they appertain. And this particular handbook possesses, in a great measure, the merits belonging to the best of the class.

In one special regard this book deserves commendation; it is not attempted to load the pocket of the user with a folio of instruction in simple arithmatic and elementary mathematics. The violent assumption that a man—the reader—must *know* these, before he sets up for a civil engineer is actually asserted in the first page of the preface! And the book at once proceeds to discussions and problems in the practice of railway construction, such as one desires to refresh his memory about, after years of disuse and forgetfulness, when the emergency arises.

In some points the tables are wanting in convenience in taking out figures. Clustering 50 lines of figures to each page, as is universal in German tables (100 lines for two facing pages), is highly advantageous. The table of logarithms of numbers would have been more useful for quick reference and field use if it had been restricted to four-figure numbering and five-figure logarithms, while for office use, the longer tables of five numbers and seven-figure logarithms is indispensible. But objections to these tables would measurably disappear as one becomes habituated to the use of them. The book needs an *index*.

We know of no compendium so convenient for ready reference, and none where tabular information has been made so dependent on the text and equally convenient to apply without chance of mistake. R. B.

THE PRINCIPLES OF THERMO-DYNAMICS, with special Applications to Hot-Air, Gas and Steam-Engines. By Robert Röntgen, Teacher Polytechnic School, Ramscheid. Translated, revised and enlarged by A. Jay du Bois, Professor Yale College, New Haven, Conn. 8vo. New York: John Wiley & Sons, 1880.

Possibly it would have been better if the title were to have acknowledged the sources of principal enlargement, Prof. Verdet, M. Pernolet, Prof. Zeuner and others, as is admitted in the preface.

The work itself is a collection of knowledge on the subject of thermo-dynamics, translated and prepared by Prof. du Bois for the use of technical classes in colleges and polytechnic institutes. While a logical course of instruction is indicated to the student by a series of questions for examination, which have been appended to each chapter.

From the practical point of view it may be remarked that too much prominence and space is given to numerous special cases of mechanisms for hot-air and gas-engines, many, if not most, of which are now merely historic curiosities, while the discussions of higher types of steam-engines, which have developed its real working existence, are imperfectly considered. The real applications of thermo-dynamic properties give sufficient grounds for study, so that the curiosities of proposition, or of startling, but unproductive, demonstration, may be set aside as a portion of the pleasant reading, "the diversions of Purley," for the learned, who have become surfeited with elementary knowledge. A chapter on cold-producing machines, for example, would become a practical study, sufficiently difficult to test the reasoning abilities of a class, and would carry with it the inculcation of positive knowledge.

Whatever might, or can, be the method or argument or course of examples of a perfect text-book on thermo-dynamics (which study ought to be one of a series of mechanical text-books, with references and cross-references throughout the series), it is certain that Prof. du Bois has collected the most thorough and practical work in the English language to this time; and that its study is made simple and easy to the mechanical engineer who has the applications of heat as one of the demands of his practice. R. B.

On Angular Aperture of Objectives for the Microscope. With Appendix and 18 full-page Illustrations. By Geo. E. Blackham, M.D., F.R.M.S. 8vo. New York: The Industrial Publication Company, 1880.

The publication before us is the reprint of a paper read by Dr. Blackham before the Microscopical Congress at Indianapolis, Ind., Aug. 15th, 1878, and is worthy to be on the table of every working microscopist. It is rarely that we meet with so clear and concise an exposition of so difficult and much disputed a subject as we find in this treatise, and we cannot but congratulate the author on the happy omission of all mathematical formulæ and calculations, which so frequently only bewilder the student of microscopy who is not an accomplished mathematician. In plain and simple language, and by the aid of excellent diagrams, we think the author has succeeded in making an intricate subject clear enough for any one to understand. The book is elegantly bound, and the press-work as well as the illustration do great credit to the publishers. C. S.

INTRODUCTION TO THE STUDY OF CHEMICAL REACTIONS. By Dr. P. E. Drechsel, Prof. Physiol. Chem. at Leipzig University. Translated by N. F. Merrill. 12mo. New York: John Wiley & Sons, 1880.

This book we confidently believe will prove of great value to the student of theoretical chemistry. It is well adapted as a companion to the usual college text-book, and gives a lucid and comprehensive explanation of chemical reactions, according to the most recent views of modern chemistry. Its exposition of the rationalistic formulæ is the most satisfactory we have seen in any text-book. R. H.

EASY LESSONS IN SANITARY SCIENCE. By Joseph Wilson, M.D., Medical Director U. S. Navy. 8vo. Philadelphia: Presley Blakiston, 1880.

Again it devolves upon us to chronicle the advent of a work upon that much-agitated subject, sanitary science. It might be construed as a favorable omen by optimists that such an amount of interest is manifested in a science which has for its object the increase of the happiness of the race, and it is not without some force of reasoning that discovery and invention are regarded as potent factors in promoting peace and comfort, inasmuch as the same mental activity which contrives those destructive engines which make war so terrible that nations hesitate to invoke hostilities to adjust their differences, also devises means to combat and exterminate those insidious and invisible enemies which assail us from various sources, and against which we have hitherto considered ourselves powerless.

The design of the little work under review appears to be to take the place of those "Primers" which supply such an important want in other sciences, namely, an insight into the broad principles underlying each department of knowledge, in order that those who cannot find time to go further may at least avoid entire ignorance—for it is now admitted that a little knowledge, far from being dangerous, is often of the utmost value, besides being all the best informed can boast of, upon many subjects.

The first half of Dr. Wilson's work is devoted to the subject of the drainage of land, and its influence upon its productiveness and the health of its inhabitants, illustrating his conclusions by circumstances

which have come under his own observation, which, although somewhat unnecessarily amplified, nevertheless serve to prove his statements to be correct.

The next subject considered is house drainage, its defects and their remedies being set forth by most appropriate cuts in connection with some important suggestions.

The writer then hastily presses on to review the drainage of cities and the important problems involved, and incidentally calls attention to the danger of drinking the water of rivers polluted with sewage, owing to the possibility of imbibing the ova of some of the entozoa infesting the human body, and suggests, as a possible remedy, wells, or filtering galleries situated adjacent to the bank of the river, from which water might be drawn freed from its impurities.

With some desultory remarks upon defective plumbing the work closes, and we think that, taken as a whole, it is probably more calculated to attract the general public than any hitherto published upon this subject. W. B. C.

Electric Lighting by Incandescence, and its Application to Interior Illumination. With 96 illustrations. By William Edward Sawyer. 8vo. New York: D. Van Nostrand. 1881.

This is a book of great practical value to all who wish to understand the subject. The style is exceptionally clear and comprehensive. We of course perfectly understand that the book is written in order to introduce the Sawyer system of lighting to the general public; therefore the closing words of the Preface, implicitly carried out as they are throughout the whole book, appear noble by comparison with many books of the same order. We quote: "Those who expect to find them devoted to criticism of the labors of other experimentalists will be equally disappointed. In the position of an impartial student and observer, I have sought less to indicate defects than to exhibit accomplishments."

Of the work 53 pages are devoted to a full description of all the types of dynamo machines, of which only ten describe the Sawyer. Thirty-three engravings fully illustrate this portion of the book. A view of each machine, with diagrams of internal construction in detail are given, and explained in the text with unusual clearness and perspicuity. Especially is this the case in the winding of the wires in the various methods of construction, so that any intelligent mechanic

could, from the drawings and text, easily construct any of these machines. The various physical laws are introduced incidentally, as occasion requires. The writer has not seen any book from which so much detail can be learned as from this.

As the Sawyer light is of the incandescent class, of course the book treats of that class in particular, devoting 61 pages of text and 32 engravings to the lamps and carbons, nearly one-half of which is taken up with other patents. The details of the Edison alone are illustrated by 7 diagrams, giving the best idea of the process of manufacturing the Edison lamp we have seen; also, a fine view of the Maxim form. As a part of the lamp, 20 pages and 5 plates are devoted to the manufacture and preservation of carbons. A page diagram is given of the Sprengel pump, as used by Edison and others. All conflicting patents appear to be given, with dates. The chemical notes beginning page 105 are excellent. His remarks, page 103, upon the comparative cost of arc and incandescent lighting present the subject so clear that we quote: "Light by incandescence is considerably more costly than light by the voltaic arc, when the volume of light obtainable is the sole consideration. The same expenditure of power that will produce a light of 1,000 candles by the voltaic arc will not produce, on an average, more than half or one-third as much light as incandescence in a divided circuit. It should not, however, be forgotten that the power of any light decreases as the square of the distance from it, and that one-fourth of the light of the arc, distributed at four or five appropriate points, thus reducing the power of each light to $\frac{1}{16}$ of that of the voltaic arc, will give substantially as good a general illumination as the arc. The incandescent light is whatever may be desired. The arc light is necessarily a powerful one. The objection to it, if used without a shade, is its great intensity and ghastly effects; and in order to obviate these defects, glass shades of more or less opacity are employed, which, according to tests, involve a wastage in light of,

With ground glass, . . .	30 per cent.
With thin opal glass, . . .	40
With thick opal glass, . . .	60

In some cases wastage is nearly 75 per cent."

Experiments in France on the Jablochkoff, with the necessary opalescent globes, "it is found that only 43 per cent. of its full power is available." "It is proper to remark that the light of the incandescent carbon is very unlike that of the voltaic arc. Its characteristics

are the characteristics of daylight; and this is true to such an extent that, from its soft and agreeable nature and absence of glaring effects, the degree of illumination afforded is not always readily appreciated." Besides, incandescent lights *do not* require shades.

Chapter 9 treats of "the division of the current and light;" a most interesting chapter because of the widely different opinions of physicists upon the subject. This should be read by all who are interested, as the author states his case and calculations clearly. If verified by future experiment they are of great value, but only actual experiment can decide.

Chapter 10 is devoted to a description of the Sawyer regulator, called here the switch—a most important part of the system, as by it the light is almost instantly turned up or down, giving any degree of intensity of light as required by the person using it. The subject is illustrated in 10 perspective and 6 diagram views, including the current regulator, one being a fine view of the Maxim governor. While these regulators admirably perform their functions, he is careful, in perfect candor, to inform the reader (page 149) that, "By means of these regulators the changes in the circuit occasioned by the Sawyer switches for graduating the light are instantly balanced. But the fact remains that as much power is expended in driving the generator when there are a few as when there are many lamps in circuit, and in a general distributing system, where economy is the prime consideration, such regulators, however perfect in their operation, can have no practical application." We venture to remark that this is not a peculiar defect of the electric light, but is a foundation principle governing every other industry.

Chapter 11 is devoted to the consideration of the Sawyer patent for lighting the buildings in the blocks of a city by electric lights. The history, plans, meters, switches, etc., requisite are fully set forth in the text and 11 diagrams. It also deserves careful study. In it the "Niagara Falls problem" is discussed at length, and, to our mind, settles that question.

The last chapter is devoted to the commercial aspects of the subject —that omnipotent question, "Will it pay?" This chapter involves so many points, exhibits so many tables and calculations, which must be most carefully studied before an opinion can be given, that we have not time this month to devote to it. It is in print, in the book, for all interested to criticise.

E. F. M.

Franklin Institute.

HALL OF THE INSTITUTE, February 16th, 1881.

The stated meeting was called to order at 8 o'clock P.M., the President, Mr. William P. Tatham, in the chair.

There were present 107 members and 85 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced, that at their last meeting, 18 persons were elected members of the Institute. Also that the Board had awarded the Elliott Cresson Gold Metal to Louis H. Spellier for his invention of the Electric Time Telegraph in accordance with the recommendation of the Committee on Science and the Arts.

The Secretary announced that at a meeting of the Committee on Science and the Arts, held February 2d, 1881, William Dennis Marks, Whitney Professor of Dynamical Engineering in the University of Pennsylvania, was elected chairman of the committee for the present year.

The following donations to the Library during the past month are reported:

Specifications and Drawings of United States Patents from March to June, 1880. From the Commissioner of Patents.

Reports of the State Board of Agriculture, etc., for 1879. From J. W. Huttinger.

The Locomotive. N. S., Vol. 1. 1880. From J. M. Allen.

Report of Light-House Board for 1880. From the Board.

Annuaire de l'Academie Royale de Belgique, 1881. From the Academy.

Electric Lighting. By W. E. Sawyer. From the Author.

Report on Standard Gauge for Bolts, Nuts, etc., for U. S. Navy.

Report on Machinery of the Steamer *Anthracite*.

Report on Experiments Tried with Horizontal Fire-tube and Vertical Water-tube Boilers.

Researches in Steam Engineering. By B. F. Isherwood. Vol. 1. From B. H. Bartol, Philadelphia.

Catalogue and Charts of the United States Coast and Geodetic Survey.

From Edward Goodfellow, Assistant in Charge of Survey Office.

James Smithson and his Bequest. By Wm. J. Rhees. From the Smithsonian Institution.

Papers read before the Pi Eta Scientific Society. Troy, N. Y.
From the Society.

Lecture on "Ye Microscope of ye Olden Time." By E. F. Moody.
From the Author.

Historical Sketch of Oliver Evans. By Rev. G. A. Latimer.
From the Author.

Thirty-fifth Annual Report of the Director of the Astronomical Observatory of Harvard College. By E. C. Pickering.
From the College.

Report on Machinery of Steamer *Anthracite*.
From the Navy Department, Washington.

Annual Report of Secretary of Treasury on Finances for 1880.
From the Secretary.

Textile Industries of Philadelphia. By Lorin Blodget.
From Chas. Bullock.

Catalogue of Brooklyn Mercantile Library. Part 3.
From the Library.

Catalogue of the Library of the Institute of Actuaries. Nov., '80.
From the Institute.

Catalogue and Address of the President of Penna. State College, 1880–81. From the College.

Report of the Commissioner of Agriculture for 1879.
From the Commissioner.

Reports from the Consuls of the United States on Commerce, No. 2.
From Secretary of State, Washington.

Reports of Commissioner of Education for 1878.
From the Commissioner.

Transactions of Institute of Mining Engineers. Vol. 8.
From the Institute.

Report of Meteorological Council to the Royal Society for 1880.
From the Society.

Circular of Information of Bureau of Education. Nos. 4 and 5. 1880. From the Commissioner.

Gold Standard. By Wm. von Kardorff-Wabnitz.
From H. C. Baird & Co., Philadelphia.

Report of Proceedings of Numismatic and Antiquarian Society of Philadelphia for 1880. From the Society.

Geological Survey of Canada. Report of Progress for 1878–9.
From the Survey Department.

Abridgements of Specifications of British Patents relating to
Dressing and Woven Fabrics. Pt. 2. 1867–76.
Manufacture of Iron and Steel. Pt. 2. 1867–76.
Electric Lighting, etc. Pts. 1 and 2. 1839–76.
Umbrellas, etc. Pt. 2. 1867–76.
Letter-press, etc., Printing. Pt. 2. 1867–76.

Disclaimers, 1874, No. 2734; 1875, No. 1204; 1877, Nos. 788. 3205, 4200; 1878, Nos. 688, 5247; 1879, Nos. 2138, 3300 and 4761.

Specifications and Drawings of Patents for Inventions. Vols. 34 to 51. (Nos. 3301 to 5100. Aug. 15 to Dec. 12, 1879.)

From the Commissioner.

The President named the following Standing Committees of the Institute for 1881:

On the Library.—Chas. Bullock, Lewis S. Ware, Dr. Isaac Norris, Robert Briggs, Henry Bower, Henry Pemberton, J. E. Mitchell, Jos. M. Wilson, Fred. Graff, Dr. W. Lehman Wells.

On Minerals.—Dr. F. A. Genth, Theo. D. Rand, Clarence Bement, Persifor Frazer, Dr. W. H. Wahl, E. J. Houston, Otto Luthy, E. F. Moody, Dr. G. A. Koenig, H. Pemberton, Jr.

On Models.—C. Chabot, H. L. Butler, Edward Brown, M. L. Orum, J. Goehring, L. L. Cheney, J. J. Weaver, S. Lloyd Wiegand, A. G. Busby, N. H. Edgerton.

On Arts and Manufactures.—J. J. Weaver, George V. Cresson, Hector Orr, Coleman Sellers, Jr., W. B. LeVan, Wm. Helme, J. S. Bancroft, Alfred Mellor, Cyrus Chambers, Jr., Geo. Burnham.

On Meteorology.—Pliny E. Chase, Hector Orr, Dr. Isaac Norris, David Brooks, Jas. A. Kirkpatrick, Alex. Purves, Dr. W. H. Wahl, F. M. M. Beale, H. Carvill Lewis.

On Meetings.—Fred. Graff, Washington Jones, Chas. H. Banes, A. E. Outerbridge, Jr., W. L. Dubois, W. H. Thorn, Cyrus Chambers, Jr., J. J. Weaver, Addison B. Burk.

A letter was read from Mr. Dalton Dorr, the Secretary of the Pennsylvania Museum and School of Industrial Art, returning a vote of thanks, from its Board of Trustees, to the Institute for the joint occupation of the rooms of the Drawing School, and regret that the increase in the number of the pupils of the schools prevented its continuance.

The Secretary's report included Edisons Electric Lights, brought on

from Menlo Park for exhibition before the Mining Engineers at their annual meeting, held this year at the Franklin Institute. There were about thirty lights, some of them rated at full power (sixteen candles), others at half and one-third power, the latter being for miners' use.

Prof. Moody, who had charge of the lamps in the absence of Dr. Moses, said that we had all heard of the wonderful things that Edison had been doing, or was going to do, and we now had an opportunity to see some of the fruits of his labors. Edison's purpose is not to produce a light of great power such as we are accustomed to see, but small lights equal to a single gas jet, for household use, and lights of one-half or even smaller size, for use in mines. There are two systems of electric lighting—one by the voltaic arc, and one by incandescence, the latter being best suited for household use. The arc lights are well represented by the Brush lights now in use for illuminating Broadway, New York, and the incandescent system is represented by the lights of Sawyer and Edison. Prof. Moody described the process of making the Edison lamps, stating that the carbon loops were now made of bamboo fibre, and were contained in an almost perfect vacuum. The resistance of the larger lamps is about 100 ohms, that of the half lamps 50 ohms, and of the others 30 ohms. The dynamo machine belonging to the Institute, which is used this evening, is not well adapted for the Edison lights. At 800 revolutions per minute, the normal rate at which it is run, the internal resistance is too great. Still it could be used with the lamps by increasing the number of revolutions to 1000. Prof. Moody also discussed briefly the different characteristics of light from gas and from electricity, saying that the latter appeared to have greater power of penetration, as shown by experience at the Hoosac tunnel.

Mr. Burk said that he could give no further information about Edison's light than he had obtained from the inventor himself. There was great difficulty originally in making the lamps uniform in resistance, and without uniformity in this respect they could not be used to good advantage on a common circuit. He had been informed, however, that the lamps could be made now with reasonable certainty, that when their resistance was measured they would fall within one of three classes—one class having a resistance of from 100 to 105 ohms, another of from 105 to 110, and the third of from 110 to 115. It was proposed now to assign one of these classes of lamps to New York and other cities, one to Philadelphia and other cities, and another to Chi-

cago, etc., and so to confine each city to lamps of a particular resistance. In this way the whole product could be utilized, and uniformity in lamps of the same circuit secured.

Mr. Orr expressed a desire to have this whole subject of electric lighting thoroughly investigated by the Institute.

Mr. Cooper inquired whether the lights as shown were as white as they could be made. He thought that they gave forth a light with more red in it than was to be seen in gas, and said that in this respect the Sawyer light seemed to him superior.

Mr. Burk said that the color depended altogether on the degree of incandescence. The light can be run up very much higher than it is shown here, and with a higher degree of incandescence it becomes whiter. But there is a limit of safety for the lamp, and it is dangerous in a public exhibition of this kind, with no regulator of the current, to run them too close to their limit, for fear of breaking the lamps and of doing an injustice to the inventor by making an apparent failure, due, not to an imperfection in the lamps themselves, but to an abuse of them. He had seen the lights at Menlo Park much brighter than these, but there the current was steadier and under perfect control. The Edison light could certainly be made as white as any other under the incandescent system, that depending wholly on the current supplied; as to whether the higher lights could be produced economically Mr. Burk had no opinion to express.

The sand blast apparatus for sharpening files was on exhibition, and its effects were illustrated by magnified sections of files as they appear when new, when worn, and after having been sharpened by the sand blast process. The apparatus consists of a steam pipe and injectors by which to drive a stream of sand and water against the files to be sharpened, the latter being carried into the blast on a carriage. The injectors are set above and below the file at an angle of fifteen degrees with it. The operation consists of simply turning on the blast, when the sand cuts away the backs of the teeth until they are brought to a cutting edge. The inventor claims that files can be sharpened by the sand blast without previous preparation and without the necessity of tempering them afterwards, as the process does not affect the temper, and that they can be sharpened by the hundred at a cost of about three cents each. One special use of the blast is the removal of the burr formed by the chisel in cutting the teeth, and which has to be worn down before a file is put in good condition.

R. D. Wood & Co. exhibited Matthews' Double Valve Fire Hydrant, which is ingeniously devised to overcome ascertained objections to the common fire plug used in this city. The new hydrant has a frost-jacket, extending from the bend at the bottom upwards to a few inches above the side-walk, and forming a "dead air chamber," to act as a non-conductor. The casing has a vertical play or motion, so that the hydrant proper, which is not pressed upon by the surrounding earth, is left undisturbed—even when the jacket is lifted by the upheaval of the ground by frost. The casing also allows the hydrant to be removed for repairs without digging up the ground. Two main or induction valves are used, and they are so connected together with the waste valve that the latter is never opened until the lower main valve is closed, and is closed before the lower main valve is opened. The movement is positive, and while the valves are in order there can be no leakage or waste. The chief advantage, however, from the use of two induction valves is that, in case of injury to the upper (usually the main valve), the latter can be taken off and the hydrant returned to its place while repairs are being made, the lower valve then becoming the main valve and keeping the hydrant ready for use. The inventor claims that the efficiency of the Fire Department of this city would be greatly increased by the use of these hydrants in place of the old-fashioned plugs, that freeze every winter, and are in constant need of repairs.

Thos. S. Speakman exhibited drawings of apparatus designed to utilize the caloric of heated gases of the products of combustion now allowed to escape up the chimney. His plan involves the use of collecting and condensing chambers, and of a blower or pump. The gases are passed through a condenser immersed in water, which latter, being heated, is used for feed water of the boilers, thus economizing fuel, while the products of combustion are separately collected, so that the carbon may be utilized as such, and the animal matter prepared for fertilizing purposes.

Mr. H. B. Hart exhibited the "Extraordinary Challenge Bicycle," which differs from the ordinary form in having the rider put farther back than usual over the rear wheel, which is made larger, to sustain the greater weight thus put upon it. The change in position of the rider makes it necessary to use levers in the propelling gear, but the pedals are directly under the saddle, and describe an ellipse instead of